

PUNA GEOTHERMAL VENTURE



PROJECT APPLICATION

Submitted by
THERMAL POWER COMPANY

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Section 1
Introduction and Summary

Section 1

INTRODUCTION AND SUMMARY

1.1 INTRODUCTION

The Puna Geothermal Venture (PGV) project consists of a two-unit 25 MW geothermal electric power plant and wellfield in the Puna District of the island of Hawaii, also known as the Big Island. Thermal Power Company (TPC) is the operator for the PGV, a joint venture of TPC and AMFAC Energy Inc.

The project site is located 21 miles south-southeast of the city of Hilo, as shown in Figure 1-1. The existing 3 MW Hawaii Geothermal Project (HGP-A) is located adjacent to the project site. The project site is situated on 500 acres of the 816-acre Kapoho state leasehold, which lies within the Kapoho geothermal subzone along the lower East Rift Zone of Kilauea Volcano. The presence of a high-quality geothermal resource capable of development has been confirmed by the exploration well at HGP-A and the PGV wells completed in 1985.

The Hawaii Electric Light Company (HELCO) has forecast an increasing need for electric energy in future years. To meet a portion of this need, HELCO has signed a contract with PGV to buy the electric energy produced by the project. HELCO currently plans to permit, construct, own, and operate the power transmission line to the project. Thus, the electric power transmission line and this project will be owned, built, and operated by different entities. The environmental impact statement for this 69 kV transmission line is being prepared by HELCO (1987) and is expected to be available for review in June 1987.

The proposed project will be constructed in two stages. In accordance with the HELCO contract and the projected need for additional power on the island of Hawaii, the planned development schedule calls for the first 12.5 MW

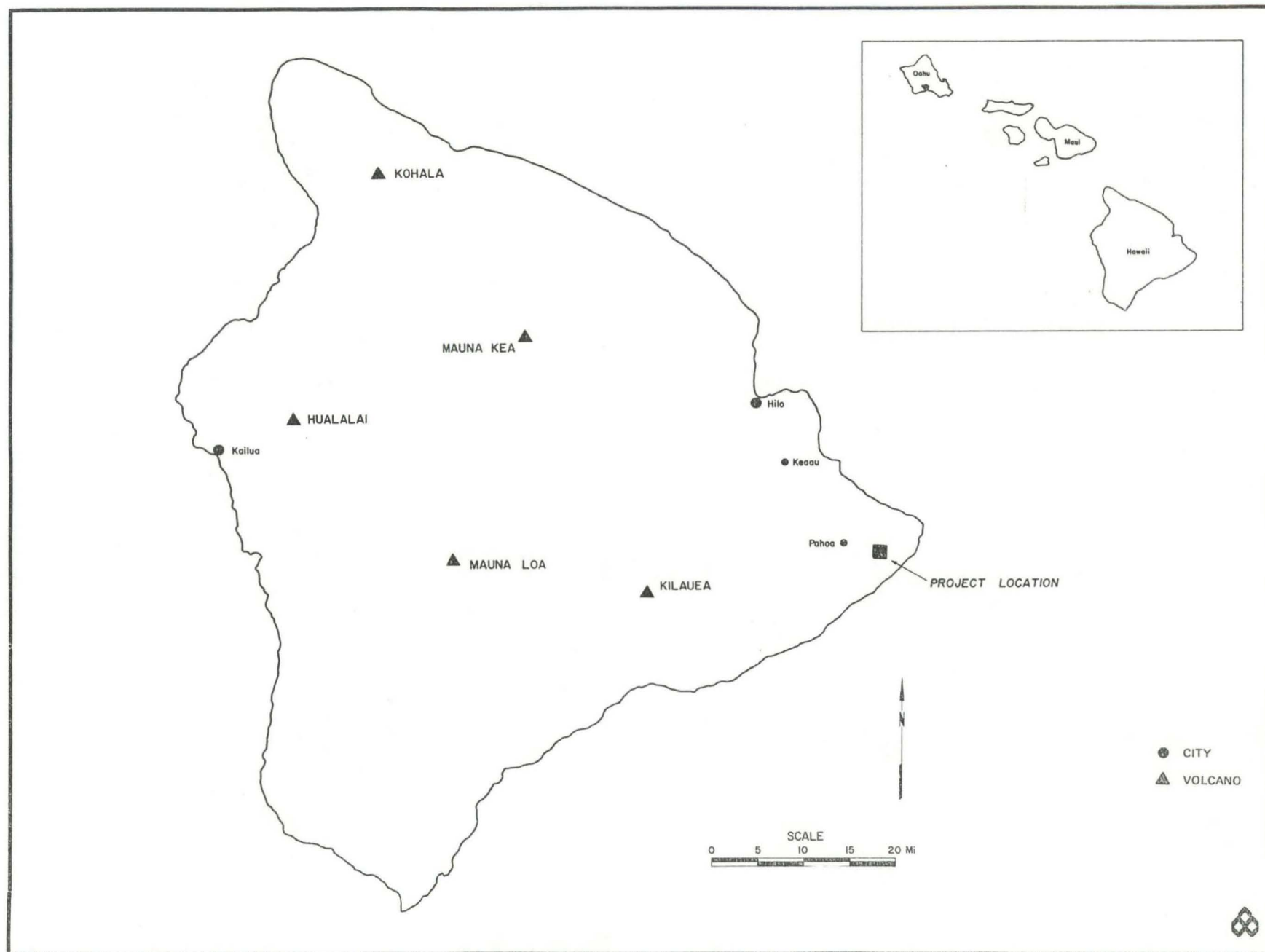


Figure 1-1 PROJECT SITE LOCATION

unit to be completed by late 1989 and the second unit to be completed by 1993. Each unit will operate independently; this redundancy enhances the already good reliability of the power plant.

Objective

The objective of this Project Application is to provide environmental and other data in a format and in sufficient detail to fulfill the requirements of all discretionary permit-issuing agencies. This document was prepared in accordance with Environmental Impact Statement (EIS) guidelines and could serve as an EIS if the appropriate regulatory agencies determine that one is necessary. It was also prepared to comply with existing permitting regulations, including the Hawaii County Planning Commission Rule 12 and the State Department of Land and Natural Resources (DLNR) Plan of Operation.

Report Content and Organization

This Project Application describes the local and regional environment in the vicinity of the project. Environmental resources that are rare or unique to the region and project site are emphasized. Included in the discussion is a description of the physical, biological, and human environment. This information is combined with the project description to predict the environmental impacts of the project. Design options to mitigate these projected impacts are also identified.

Baseline environmental studies of the PGV project began in early 1980. The Bernice Pauahi Bishop Museum conducted an archaeological survey of the project study area, and Belt, Collins & Associates was contracted to assess the human environment in the Puna District. Independent consultants associated with the University of Hawaii performed a biological field survey of the flora and fauna and an analysis of the ecosystem within a 1-mile radius of the project area. TPC has conducted ongoing monitoring studies of baseline ambient air quality in the Puna District since 1981. These and other baseline studies provide a detailed assessment of the existing environment and a reference point for determining future changes.

Background

Purpose and Need. The purpose of the PGV power plant project is to supply electrical power to help meet a shortage in the HELCO system demand forecast. This forecast projects need for substantial new capacity by 1989 and an additional increment by 1991. The island of Hawaii is electrically isolated and must satisfy its own electrical needs. These needs for sufficient capacity must be satisfied in an economic and dependable manner. A two-unit geothermal plant of 25 MW capacity was selected as being consistent with those objectives.

The replacement of imported oil with power generated from renewable resources is the objective of both state and county plans designed to increase Hawaii's energy self-sufficiency (Hawaii State Plan, 1978, Chapter 226, Hawaii Revised Statutes; General Plan, County of Hawaii as amended). Electrical power from the Puna geothermal power plant, produced from an indigenous energy resource, will allow HELCO to reduce its use of imported oil by approximately 250,000 barrels per year.

Over the longer term, the state and private developers hope to increase the energy self-sufficiency of the state by constructing an inter-island power cable. The full geothermal potential of the island of Hawaii could then be developed to supplement the needs of the larger market on Oahu. However, supplying power to Oahu is beyond PGV's current known reservoir capacity and the scope of its development plans.

History of Geothermal Development in Hawaii. The Big Island's use of geothermal resources was started by early Hawaiians, who used the Kilauea summit fumaroles for cooking and heating. But it was not until 1961, when four holes were drilled in the Kilauea East Rift Zone by a private company, that commercial use of geothermal heat was explored. Temperatures encountered were much higher than those of normal groundwater. However, because the wells were so shallow, they did not have commercial potential.

Twelve years later, a research well was drilled at the Kilauea summit to a depth of 4,141 ft (1,262 m). The temperature of fluids at the bottom of the

well was 275°F (135°C), and there were indications of much higher temperatures at greater depths. At approximately the same time, the University of Hawaii started an exploration program for a second exploratory well. Based on factors such as numerous shallow warm-water wells in the area, geophysical anomalies, and land availability, a 6,540 ft (1,994 m) well, HGP-A, was drilled in 1976 in the lower East Rift Zone, approximately 3,281 ft (1 km) southwest of the prehistoric cinder cone Pu'u Honua'ula. The HGP-A well has the distinction of being the hottest well in the United States, with a measured bottom hole temperature of approximately 676°F (358°C).

In 1981, construction was completed on a 3 MW wellhead generator facility, designated as the HGP-A plant. Its construction was sponsored by the county and state of Hawaii and the U.S. Department of Energy (DOE). This plant has operated continuously since then, producing more than 19 million kWh of electricity per year. It has established the technical feasibility of commercializing the resource and has demonstrated reliability of operation.

1.2 SUMMARY

The following summarizes the various sections of this report and highlights conclusions that can be made, based upon the environmental work performed to date. This summary must be used in conjunction with the rest of the document, however, since it is not a substitute for the analysis contained in later sections.

Description of the Proposed Action

Facilities Description. The proposed geothermal power project consists of two 12.5 MW units (25 MW total), associated wells, and steam supply and fluid disposal systems.

The geothermal resource produces a mixture of steam and brine from the production wells. A separator on each wellpad will divide the mixture into steam and brine streams, as shown in Figure 1-2. The steam then flows through collection and transport piping to the power generation facilities. A second piping network collects the brine, which is returned to the reservoir.

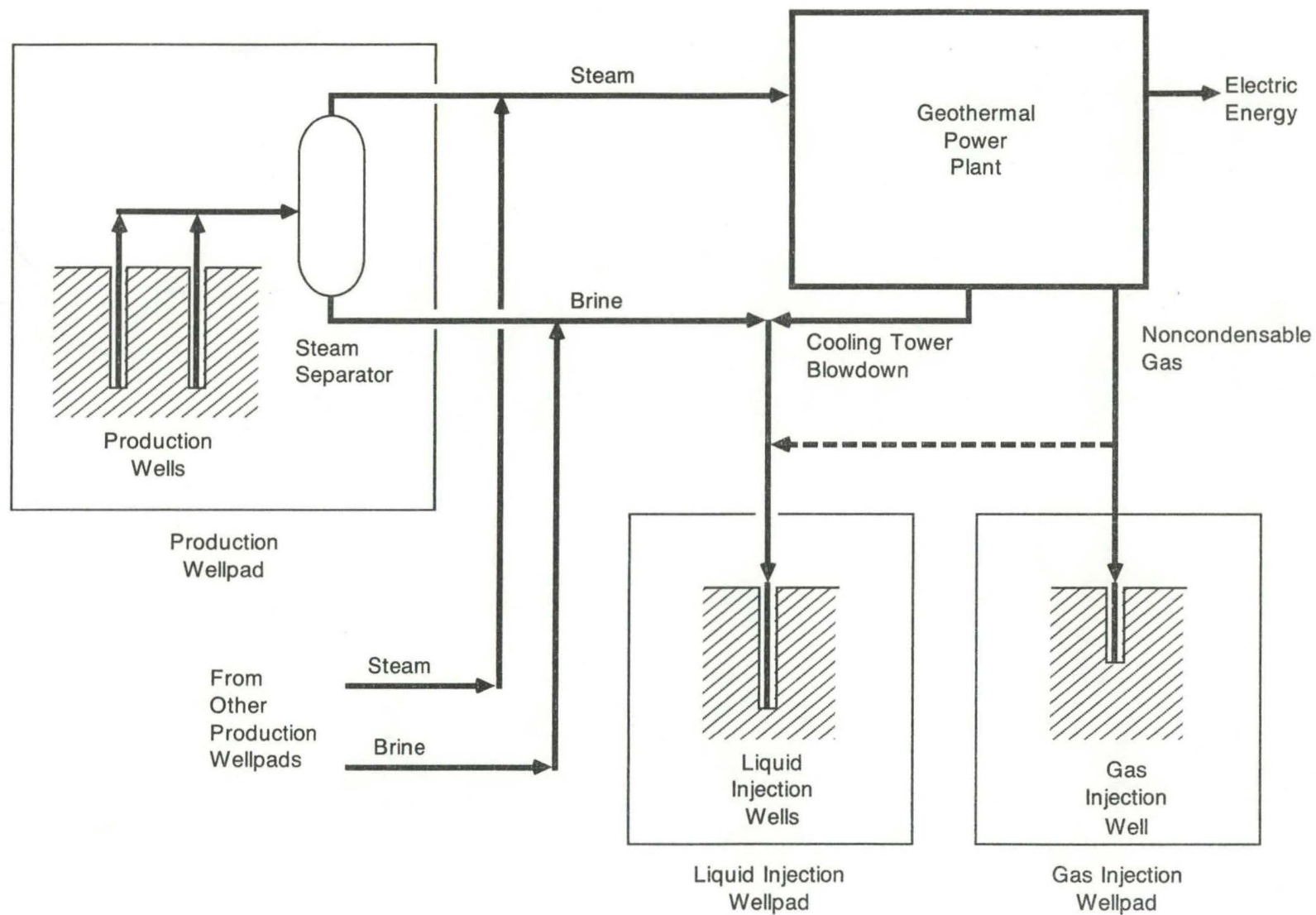


Figure 1-2 WELLFIELD AND POWER PLANT SCHEMATIC ARRANGEMENT

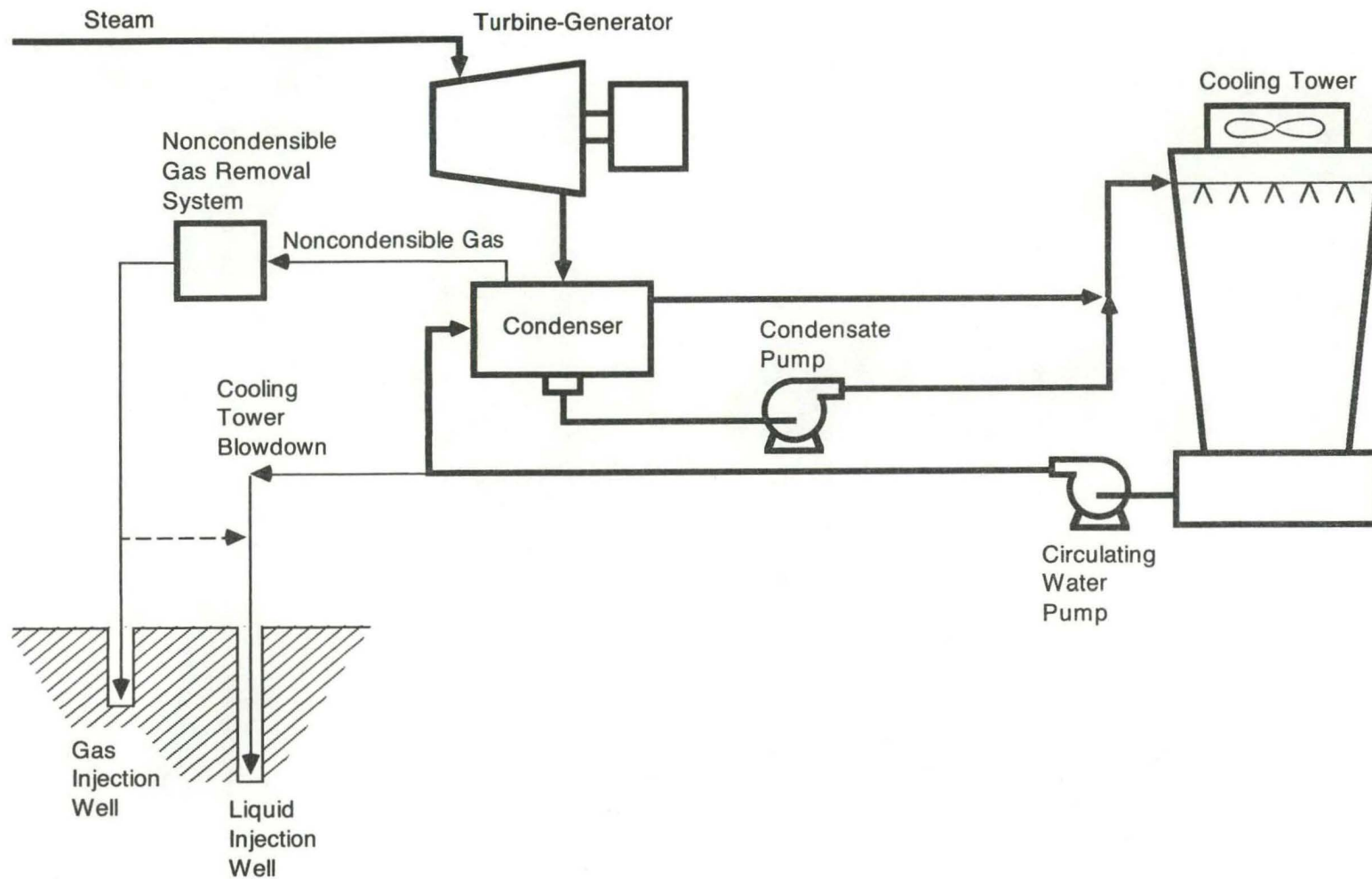
The steam is supplied to the two 12.5 MW turbine-generator units. A schematic diagram of one unit is shown in Figure 1-3. The turbines exhaust to condensers where steam-driven jet ejectors remove the noncondensable gases, which include most of the hydrogen sulfide (H_2S). These gases are then injected into a nonreservoir geologic stratum. When the turbine-generator is not operating, a turbine bypass system routes the steam flow directly to the main condenser to allow H_2S removal and disposal as described above.

The cooling tower basin supplies cooling water for the main condensers and plant auxiliaries. Heat from the water is expelled to the environment through a mechanical draft cooling tower. The steam condensate (geothermal steam condensed during power plant operation) serves as the source of makeup for the water evaporated in the cooling tower. This fluid contains the smaller fraction of the H_2S not removed from the condenser with the noncondensable gases and disposed of by injection into the formation. The cooling tower blowdown will be combined with the brine fraction from the wellpad separators and injected back into the reservoir. Blowdown is excess cooling water with elevated dissolved solids that is continuously discharged to maintain a low level of dissolved solids in the circulating cooling water system.

A steam release facility consisting of a rock-filled muffler and an H_2S abatement system is used to vent steam to the atmosphere when it cannot be accepted in either the steam turbines or steam bypass facilities.

Natural Resource Requirements. The steam requirement for the two generating units is approximately 430,000 lb/hr. Land requirements will be approximately 12 acres for the power plant, wellpads, steam lines, and access roads. Water consumption will be approximately 3.2 million gallons per year (gpy) for cooling tower consumption during operation of the turbine bypass system and for H_2S abatement during steam venting through the rock muffler. The water is supplied by an on-site rainwater collection system and the storage of excess steam condensate not needed for cooling tower makeup.

Environmental Discharges. Discharges from the power plant will include liquid and noncondensable gas (including H_2S) fluids, and waste heat.



8-1

Figure 1-3 SCHEMATIC DIAGRAM OF ONE UNIT

Current data indicate that the quantity of brine to be injected is approximately 190 gallons per minute (gpm), but the actual amount cannot be determined until the wellfield has been completed. The amount of condensate blowdown is a function of operating conditions; during normal operations, there will be approximately 90 gpm available for injection. The total volume of liquid requiring injection, therefore, is on the order of 280 gpm.

The amount of noncondensable gases to be injected is approximately 800 lb/hr, but since some steam carryover and air leakage will also be in the noncondensable gas flow, about 1,000 lb/hr (455 kg/hr) of gaseous fluid will be injected.

The only gaseous emission of concern is H_2S , which would be discharged primarily from the cooling tower stacks. If required, this emission will be controlled to meet appropriate regulatory requirements by chemical injection. Thermal discharge from the cooling towers to the atmosphere will be approximately 400 million Btu/hr.

Construction. The total project construction time for startup of the first unit is estimated to be 18 months after the start of site-preparation activities. Construction of the second unit will begin 6 months after completion of the first, and is estimated to take 18 months also. Estimated peak employment at the site during construction of each unit is expected to be up to 100 people. The plant is designed to operate unattended, but staff normally will be present three shifts per day for safety and security considerations.

Decommissioning. When economic and resource conditions dictate that the power generation project be abandoned, the plant and wells will be decommissioned, and the site restored to an environmentally compatible condition.

Description of the Environmental Setting

Physical Environment. The project site lies within the South Pacific trade wind belt. The trade winds dominate the climate of the island. Winds at Hilo average 7.2 mph (3.2 m/s) year round. Clear skies are rare, as clouds

frequently form on the upslope sides of the mountains. Showers are frequent, varying from sudden sprinkles to heavy downpours. Between 1931 and 1960, the normal annual rainfall at Hilo Airport was 135.6 in. (3,470 mm). Temperatures remain steady throughout the year with a normal monthly mean temperature of 75.9°F (24.4°C) for August, which is the warmest month, and 71.0°F (21.7°C) for February, which is the coolest month.

The island of Hawaii lies at the southwestern end of the Hawaiian archipelago and is the largest and youngest of the chain. The project site is located on the flank of Kilauea Volcano along its east/northeast trenching rift, commonly referred to as the East Rift Zone. The site is entirely underlain by highly permeable basaltic lava flows and associated ejecta of the Puna Volcanic Series. Thin soils of the Keaukaha, Opihikao, and Malama soil series cover approximately 75 percent of the site. There are no naturally occurring surface water drainages at the site, and groundwater resources generally are acknowledged to be of low quality.

The geothermal reservoir to be developed by the project is located within the East Rift Zone at a depth of 1.4 mi (2.3 km). The geothermal reservoir is in fractured basalt, through which the geothermal fluids circulate. The reservoir is capped by impermeable rock, and the fractures are sealed by secondary mineral deposition.

Biological Environment. The vegetation types in the Puna District are determined by the various lava flows there. Vegetation on the younger lava flows consists of scattered low brush with a solid carpet of white lichen. In comparison, vegetation on the older and deeply weathered flows consists of a closed forest with a well developed shrub and herb layer. Two hundred forty plant species were identified within 1 mile of the project during botanical surveys in 1984. Of these, 65 (27 percent) are native species, 12 (5 percent) were introduced by the Polynesians, and 163 (68 percent) were introduced subsequently. There are five species of rare endemic plants in the general vicinity of the project site, but none should be affected by the proposed project.

Large areas of the Puna District support agricultural activities. A substantial portion of the project site area is now or recently has been under papaya cultivation.

The primary faunal species of interest in the study area are birds. Two native and nine introduced bird species were observed in the project site area. One of the native species, the Hawaiian hawk, is currently on the federal list of endangered species.

Human Environment. The Puna District is a rural area. Most of its land is covered by natural vegetation and is classified as Conservation District Land. The second most extensive land use in the district is agricultural; the project site is on agricultural land. During the 1950s and 1960s, large portions of the district were subdivided into residential lots. However, much of that land remains vacant and unimproved.

The aesthetic character of the Puna District and project site is defined by topographic features and natural or agricultural vegetation. Because of the area's relatively high rainfall, the overall impression is of lush growth; in contrast, the most recent lava flow areas are black and barren.

A marked population increase (+128 percent) occurred in the Puna District from 1970 to 1980. Puna's 1980 population of 11,751 made it the third most populous of the island's nine judicial districts. The population growth may have stemmed in part from the abundant supply of relatively low-priced residential and agricultural land.

For the past several decades, the basis of the island's economy has gradually changed from agriculture to tourism. However, comparing island-wide labor force statistics with those of the rural Puna District, one finds proportionally more 1980 Puna workers engaged in manual occupations such as farming, fishing, and forestry, or in precision/repair work, than in tourism-related occupations.

The island of Hawaii is rich in cultural history. The Puna District, in particular, was an important center in the development of Hawaiian religion. Paa'o established his line of priesthood at Puna, and it continued there until after the death of King Kamehameha in 1819. However, an archaeological reconnaissance survey of the project area found no archaeological sites or cultural remains.

Probable Environmental Impacts of the Proposed Action

Physical Environment. Construction of the PGV project will result in minimal temporary fugitive dust and diesel emissions from heavy construction equipment. In addition, well drilling and testing may result in emissions of H_2S and total suspended particulates. During operation of the power plant, controlled noncondensable gas emissions will include CO_2 , N_2 , H_2 , and water. Also, particulates will be emitted by the cooling tower. Both particulates and H_2S emissions will be within regulatory limits of proposed or adopted state emission standards in force at the time of construction. No emission limits have been proposed or adopted for other plant emissions. Decommissioning of the project facilities will result in diesel and total suspended particulate emissions from heavy construction equipment that are similar to those of the construction phase.

Project development impacts on geology, soil, and hydrology will be limited to alteration of site topography from excavation, temporary increased erosion from soil disturbance, and potential discharges to nonpotable basal groundwater.

Biological Environment. Construction, operation, and decommissioning of the project are expected to have no significant impacts on the biological environment. Disturbance of the natural vegetative communities during the construction phase will be minimal. The project is expected to have no effect on the rare endemic plants in the project vicinity. In addition, limited disturbance of mammal and bird species habitats may occur as a result of project construction and operation. The endangered Hawaiian hawk uses the project area for hunting rodents and other prey but does not nest close to the site. The proposed project is not expected to cause any significant impacts

to the Hawaiian hawk because ample hunting area is available nearby, and the hawks are already accustomed to human activity in the papaya fields.

Human Environment. A 12-acre commitment of land will be required for development over the project's 35-year life. This commitment will cause a maximum loss of less than 1 percent of the orchard land leased by PGV.

Peak construction will require about 100 employees. Approximately 19 employees will be required for operation and maintenance of the 25 MW facility. It is estimated that the annual operating expenditures for labor will be \$700,000.

Economic activity generated by the project will have an effect on both the economic output of Hawaii County and the personal income of its residents. The county's economy will be affected by the following expenditures:

- o Capital expenditures related to direct expenditures on goods, services, and wages during construction
- o Operating expenditures, including employee salaries

County revenue from the proposed project will be primarily in the form of property taxes. Other revenue will be received from motor-fuel tax, licenses, and permit fees.

The aesthetic character of the area will be affected to a minor extent by the intrusion of construction activities. Several visual changes may occur during construction and operation, including:

- o Removal of vegetation
- o Minor changes of landforms by excavation and grading
- o Installation of new structures
- o Steam plumes from cooling towers and well testing

During the initial phases of the project, power equipment used to construct roads, wellpads, and pipelines will generate noise. To mitigate

noise, construction normally will be restricted to daylight hours, and noise-level restrictions and time constraints will be obeyed in compliance with county noise guidelines. Some noise from cooling tower fans will also occur during operation. There is a potential for some H₂S odor from time to time. Normal precautions will be taken to ensure that occupational hazards at the plant will be well within or below the normally accepted standards. Projected impacts from the project construction and operation on adjacent residential, agricultural, and recreational land uses are expected to be minimal.

Unavoidable Adverse Environmental Impacts

The majority of the impacts identified as a result of project development will be mitigated to minimize the overall effects during construction, operation, and decommissioning. However, as with any project, there will be some unavoidable environmental impacts. Development of this project will have the following adverse environmental impacts that cannot be mitigated or avoided:

- o Minor alterations to topography
- o Controlled quantities of air emissions during well drilling and testing, and during construction (within regulatory standards)
- o Controlled quantities of air emissions during power plant operation (within regulatory standards)
- o Controlled discharges to groundwater during well drilling and testing (within regulatory standards)
- o Discharges to groundwater from injection operations (consistent with regulatory standards)
- o Commitment of land
- o Visual disturbance to the existing landscape
- o Controlled noise during construction, well drilling and testing, and plant construction, operation, and decommissioning (within regulatory guidelines)
- o Increased traffic during construction

Air and water quality impacts will be minor and will be controlled to adhere to strict federal, state, and county regulations and environmental guidelines. Most of the above impacts, especially air and water quality impacts, will occur only during the life of the project. Following project decommissioning, many of these unavoidable impacts will be mitigated through site restoration.

Irreversible and Irretrievable Commitment of Resources

The PGV project will require the commitment of land, geothermal fluids, and building materials. The irreversible and irretrievable commitments of resources will be limited to geothermal fluids, the building materials needed to construct and operate the proposed geothermal facility, and the associated capital development costs.

Proposed Impact Mitigation Measures

The mitigation measures associated with the plant construction, operation, and decommissioning impacts are summarized in Tables 1-1 through 1-3. Mitigation measures necessary to meet regulatory requirements and other measures deemed appropriate by the project developer are also summarized.

Necessary Permits

The permits and approvals applicable to the PGV project are presented in Table 16-1.

1.3 CONCLUSIONS

Based on the preliminary plant concept, the PGV project is expected to have minimal impact upon the physical, biological, and human environment at the project site and in the surrounding area. Mitigation measures to reduce all impacts to a level consistent with existing and expected regulations are included in the project plan.

Table 1-1

**SUMMARY OF PROPOSED MITIGATION MEASURES
FOR CONSTRUCTION IMPACTS**

<u>Construction Impact</u>	<u>Mitigation Measures</u>
<u>Physical Environment</u>	
Air emissions	<ul style="list-style-type: none"> o Design well drilling operations to include emission controls in compliance with strict state regulations. o Use motor vehicle exhaust emission control equipment and provide maintenance of drilling and construction equipment. o Suppress dust on disturbed areas by spraying water during dry periods. o Remove or stabilize loose or disturbed earth.
Topographic alteration	<ul style="list-style-type: none"> o Minimize earthwork activities.
Erosion	<ul style="list-style-type: none"> o Minimize earthwork and other disturbance activities. o Reuse backfill. o Dispose of spoils in designated areas. o Stabilize excavated areas and stockpiles. o Implement a revegetation program in all disturbed areas after construction.
Liquid spills	<ul style="list-style-type: none"> o Implement a spill prevention, control, and containment program for construction activities. o Implement prompt spill cleanup procedures consistent with applicable regulations.
<u>Biological Environment</u>	
Disturbance of endangered or special-interest species and/or habitat	<ul style="list-style-type: none"> o Limit construction activities to a minimum distance from critical species habitat. o Continue monitoring the area used by the Hawaiian hawk.

Table 1-1 (Cont'd)

<u>Construction Impact</u>	<u>Mitigation Measures</u>
<u>Human Environment</u>	
Land clearing	o Select a plant site to minimize displacement of productive agricultural lands.
Public concerns	o Implement community involvement and education programs. o Develop contingency management plans for dealing with public concerns. o Prepare emergency plans to coordinate federal, state, county, and developer actions in the event of an accident threatening public health or safety.
Aesthetic intrusion	o Maintain a neat and orderly project construction site. o Develop an aesthetic project design with landscaping.
Noise	o Use drilling and construction vehicle noise suppression equipment. o Use noise control equipment and procedures to keep noise-generating activities within legal limits and guidelines.

Table 1-2

SUMMARY OF PROPOSED MITIGATION MEASURES
FOR OPERATIONAL IMPACTS

<u>Operational Impact</u>	<u>Mitigation Measures</u>
<u>Physical Environment</u>	
Air emissions	<ul style="list-style-type: none"> o Use injection for noncondensable gas or the incineration process as an alternative. o Continue the air monitoring program. o Use emission-controlling plant process equipment in compliance with applicable state regulations. o Use the steam bypass system. o Use cooling tower drift eliminators.
Site seismic and volcanic activity	<ul style="list-style-type: none"> o Locate and orient structures to minimize seismic impacts. o Use structural design in accordance with applicable codes. o Provide for wellhead protection.
Water quality	<ul style="list-style-type: none"> o Inject fluids into aquifers with poor water quality. o Line all settling ponds. o Develop and implement a groundwater monitoring program. o Develop and implement an operation spills prevention program to protect water quality.
Spills	<ul style="list-style-type: none"> o Implement prompt spill cleanup procedures in compliance with regulations. o Locate berms around storage areas to contain liquid spills. o Use injection, rather than surface air abatement methods, for noncondensable gases to reduce the amount of chemicals shipped. This minimizes the possibility of spills.

Table 1-2 (Cont'd)

<u>Operational Impact</u>	<u>Mitigation Measures</u>
<u>Biological Environment</u>	
Disturbance of endangered or special-interest species and/or habitat	<ul style="list-style-type: none"> o Implement air emission mitigation measures. o Implement noise mitigation measures.
<u>Human Environment</u>	
Public concerns	<ul style="list-style-type: none"> o Continue to expand the community involvement programs to foster understanding of geothermal development. o Develop contingency management plans for dealing with public concerns related to geothermal development. o Develop emergency contingency plans.
Noise	<ul style="list-style-type: none"> o Incorporate noise control measures in plant design. o Design equipment and operating procedures to keep noise generated by plant activities within legal limits.
Health and safety	<ul style="list-style-type: none"> o Implement air emission mitigation measures. o Implement noise mitigation measures as stated above. o Implement worker health and safety plans and education programs in accordance with applicable regulations.

Table 1-3

SUMMARY OF PROPOSED MITIGATION MEASURES
FOR DECOMMISSIONING IMPACTS

<u>Decommissioning Impact</u>	<u>Mitigation Measures</u>
<u>Physical Environment</u>	
Air emissions	<ul style="list-style-type: none"> o Use exhaust emission control equipment and provide regular engine maintenance of construction equipment used in decommissioning. o Suppress dust on disturbed areas by spraying water during dry periods.
Erosion	<ul style="list-style-type: none"> o Minimize earthwork and other disturbance activities. o Dispose of spoils in designated areas. o Recontour excavated areas to near pre-project topography. o Implement revegetation programs in all disturbed areas.
Spills	<ul style="list-style-type: none"> o Implement a spill prevention program for decommissioning activities. o Implement prompt spill cleanup procedures.
Water quality	<ul style="list-style-type: none"> o Adhere to accepted methods of well plugging and abandonment. o Continue water quality monitoring for 2 years.
<u>Biological Environment</u>	
Disturbance of endangered or special-interest species and/or habitat	<ul style="list-style-type: none"> o Limit decommissioning activities to a minimum distance from critical species habitat.

Table 1-3 (Cont'd)

<u>Decommissioning Impact</u>	<u>Mitigation Measures</u>
<u>Human Environment</u>	
Land use	<ul style="list-style-type: none">o Return land to near-original conditions.o Plant natural vegetation and/or agricultural crops, or as specified by lease agreements.
Aesthetic intrusion	<ul style="list-style-type: none">o Maintain neat and orderly project decommissioning operations.o Restore the project site by contouring and revegetation.
Noise	<ul style="list-style-type: none">o Use vehicle noise suppression equipment.o Utilize equipment and procedures to keep noise-generating activities within legal limits.

Section 2
Description of the Proposed Action

Section 2

DESCRIPTION OF THE PROPOSED ACTION

This section contains a review of the proposed action. It includes descriptions of the geothermal wells, the wellfield pipelines, the power plant, the construction schedule, operation and maintenance staffing, and the decommissioning plan.

2.1 GEOTHERMAL LAND POSITION

Land Position

The project is to be developed on about 500 acres of the 816-acre parcel subleased from the Kapoho Land Partnership (KLP) by the PGV (Tax Map Key 3-1-4-01: portions of 2 and 19). The sublease includes both surface and geothermal rights. KLP holds the surface rights to the parcel and has obtained a State of Hawaii Geothermal Mining Lease, which includes the rights to the geothermal resource. It was necessary for KLP to obtain mining leases to the property because the state of Hawaii claims the right to the geothermal resources.

Geothermal Resources Subzone

Act 296, Session Laws of Hawaii, 1983, and Act 151, Session Laws of Hawaii, 1984, enacted changes to the Land Use Laws (Chapter 205, HRS) by establishing procedures for "geothermal resource subzones" to be designated by the Board of Land and Natural Resources (BLNR). Under the legislation, geothermal activities within the subzones are to be regulated by county and state rules.

The entire 816-acre sublease from KLP has been designated as a geothermal resource subzone under the terms of Chapter 205-5, HRS.

2.2 GEOTHERMAL FLUID PRODUCTION AND INJECTION

Geothermal Resource

The Puna geothermal resource is located in the area known geologically as the Kilauea East Rift Zone. The geothermal reservoir tapped by present drilling exists within about a 0.6 mi (1 km) rift trend with geologically recent faulting and lava extrusions. A conceptual model of the Puna geothermal reservoir is shown in Figure 2-1. The heat source for the geothermal system is a deep, magmatic conduit or dike complex that underlies the reservoir. The geothermal reservoir is a two-phase, liquid-dominated system with variable steam fractions. The average reservoir temperature is approximately 650°F.

The range of effluent chemistry from a wellbore exploiting the hydrothermal reservoir is presented in Table 2-1. The noncondensable gas composition is given in Table 2-2. The virgin reservoir fluid is thought to contain a brine with a minimum of 6,300 ppm by weight total dissolved solids (TDS) content. When flashed at the surface, the dissolved solids content of the separated brine rises to as much as 36,000 ppm TDS. The brine will be injected back into the reservoir or at reservoir depths.

The separated steam is chemically very clean, with a TDS content less than 36 ppm. The noncondensable gas content of the flashed steam fraction is approximately 2,200 ppm by weight, with approximately up to 1,300 ppm by weight H_2S content.

The project site is situated over an immense groundwater system, which occurs in basalt layers, joints, vesicles, and shallow intermittent ash beds above the geothermal reservoir. The local groundwater table lies at about 600-foot depth. The groundwater itself is brackish, resulting from natural geothermal leakage and saltwater intrusion, and can be labeled as geothermal water.

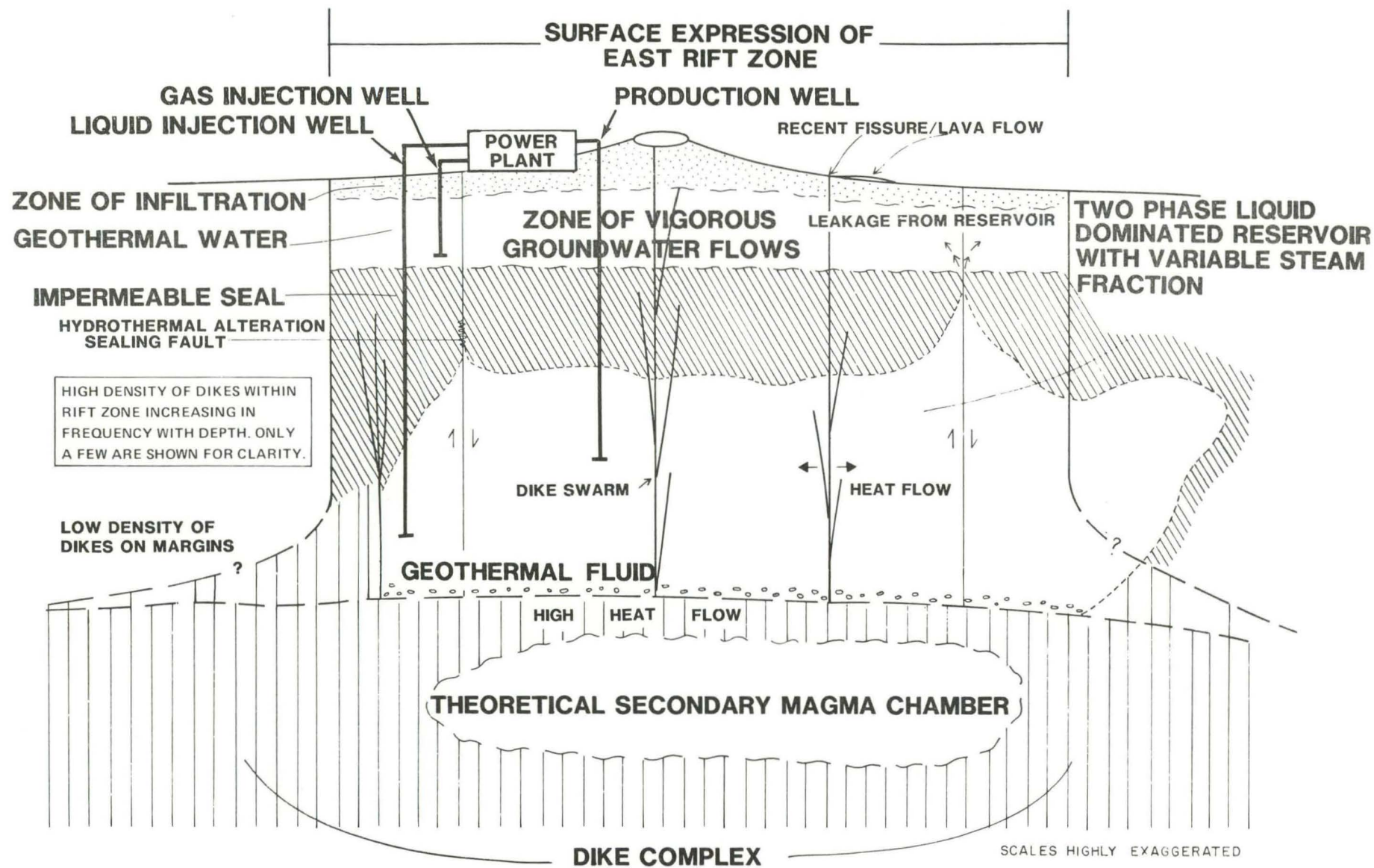


Figure 2-1 CONCEPTUAL MODEL OF PUNA GEOTHERMAL SYSTEM

Table 2-1

GEOTHERMAL FLUID CHEMICAL COMPOSITION
COMPOSITE DATA^(a)

<u>Element</u>	<u>Brine (ppm)</u>	<u>Steam Condensate (ppm)</u>
Na	1,436 - 10,560	0.14 - 0.24
K	207 - 2,700	0.1 - 0.2
Ca	30 - 950	<0.1
Mg	0.26 - ≤ 10	<0.1
Fe	<0.01 - 9.8	0.04 - 0.11
Mn	0.21 - 8.8	--
B	4.3 - 11	<0.5
Br	20 - 89	--
I	<1 - <20	--
F	0.25 - 1.6	<0.1
Li	1.1 - 8.7	<0.01
Cl	2,417 - 21,000	<2
NH ₃	0.11 - 0.17	<0.1 - 0.32
SO ₄ ^(b)	8.8 - 61	7.1 - 21
Hg	<0.001 - <0.05	<0.5
As	0.04 - 0.6	≤ 0.01 - <0.5
S ^(c)	3.2 - 15	790 - 1,100
HCO ₃	1.2 - ≤ 12	--
CO ₃	0	--
SiO ₂	794 - 2,000	<0.03 - 1.0
Total S (dis)	6.1 - 35	2.7 - 8.3
TSS	<50 - 80	--
TDS	5,000 - 36,000	<10 - 36
pH	4.5 - 8+	3.3 - 3.6

(a) Composite data from three wells on the PGV site (KS-1, KS-1A, and KS-2) and the HGP-A well.

(b) Concentration high due to oxidation of S⁼ to SO₄.

(c) Concentration low due to oxidation of S⁼ to SO₄.

Table 2-2

NONCONDENSABLE GAS COMPOSITION
COMPOSITE DATA (a)

<u>Element</u>	<u>Content in Steam (ppm)</u>
CO ₂	250 - 1,042
H ₂ S	165 - 1,300
NH ₃	<0.034 - 13
N ₂	10 - 670
CH ₄	<0.082 - <0.2
He	<0.0027 - <0.0065
H ₂	3.7 - 25

(a) Composite data from three wells on the PGV site (KS-1, KS-1A, and KS-2) and the HGP-A well.

Notes: KS-2 needs permit to clear wellbore. Defunct, lost KS-1A recorder, 1/20/84. 1/20/84.

Production Wells

The site plan for the wellfield and 25 MW power plant is shown in Figure 2-2. The wellfield development plan anticipates six production wells to meet the initial steam supply requirements of the 25 MW power plant. The first 12.5 MW unit requires three production wells; two existing wells, KS-1A on Wellpad A, and KS-2 on Wellpad B, may be used as production wells. One or more additional production wellpads with one or two wells are required for the initial development phase of 12.5 MW.

In addition to the initial six production wells for the 25 MW power plant, approximately nine makeup production wells are anticipated over the plant's 35-year life. These additional wells will be drilled on existing wellpads or on additional Wellpads C, D, and E, as needed.

For planning purposes, each production well is anticipated to have an average flow rate of 90,000 lb/hr of total geothermal fluid. The decline in flow for each well is projected to average 3 percent per year. Wellhead pressures of flowing wells are expected to be in the range of 160 to 180 psig, and wellhead temperatures in the range of 370° to 380° F.

Detailed well drilling and completion procedures are contained in the submissions to DLNR for individual well permits under Title 13, Chapter 183, Hawaii Administrative Rules. Production wells will be directionally drilled to an average depth of 7,600 feet. A standardized casing program is required to protect the environment, groundwater, geothermal resources, life, health, and property. It will consist of 13-3/8-inch-diameter steel casing to about 2,500 feet, 9-5/8-inch production casing to about 4,100 feet, and 7-inch perforated lining to about the bottom. All casings are steel and are joined and cemented to ensure the integrity of the wellbore from the surface to the producing zone. Blowout prevention equipment (BOPE) capable of shutting in the well during any drilling operation is used to prevent any uncontrolled escape of geothermal fluids (well blowout) during drilling.

After drilling, a flow test is conducted on each production well to determine its commercial value. The testing procedure includes a minimum

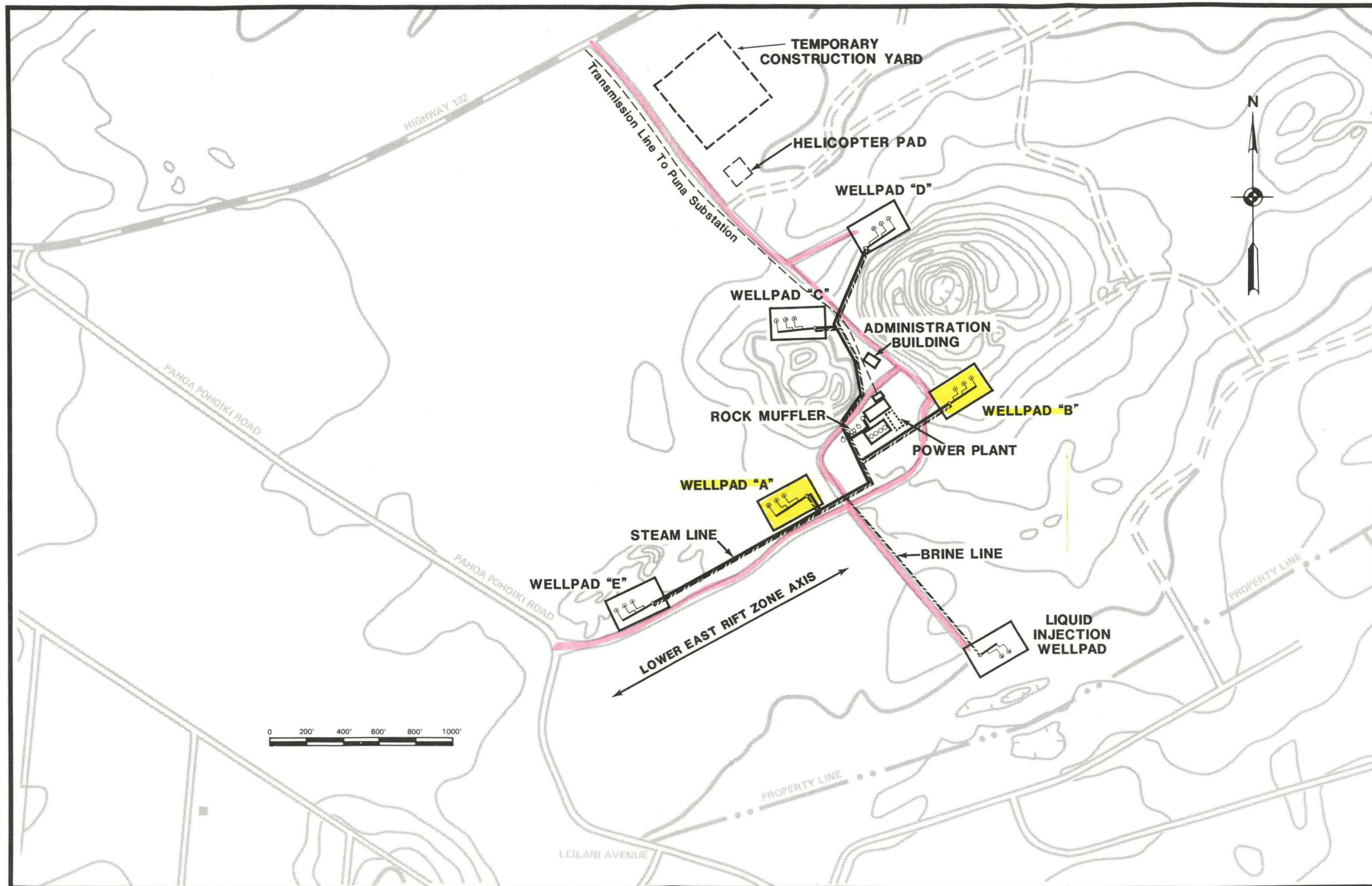


Figure 2-2 SITE PLAN

What level of H₂S control efficiency is expected?

period (2 to 4 hours) of vertical venting to clean the wellbore of
particulates; this is followed by a flow test to measure mass flow rate, brine
fraction, temperature, and fluid composition. Noise and chemical abatement
systems are employed during most of the flow test, but a brief period of
unabated vertical venting at the initial opening is needed to clear the well.
The duration of the flow test is variable. Initially, flow tests may run up
to 7 days; as more experience is gained, 24- to 48-hour flow tests may be
adequate.

Is it necessary to have a flow test to determine the appropriate flow rate?
If so, what flow rate is expected? How long will it take to reach the
production rate?

Liquid Injection Wells

One liquid injection well is initially required for the power plant, with
an additional two or three replacement wells anticipated throughout the plant
life. Idle existing wells in the area or marginal production wells are
considered as preferred candidates for conversion into injection wells;
however, all data must be reviewed to determine the appropriateness of such
wells as injectors. If a new injection well must be drilled, it will be
directionally drilled into the southern edge of the reservoir from an
injection wellpad.

What are the existing plans and there is the drilling of a new
injection well. It is being constructed at the site for power.

Each injection well will be encased with steel and cemented to the depth
of the injection zone, 4,000 to 7,000 feet below the surface. The injection
zone will comply with health and safety regulations and permit conditions
determined by the State of Hawaii Department of Health. Drilling permits will
be obtained from DLNR.

Gas Injection Wells

Is it necessary to have a flow test to determine the appropriate flow rate?
If so, what flow rate is expected? How long will it take to reach the
production rate?

One gas injection well is initially planned for the power plant, although
replacement wells may be required over the plant life. The injection zone is
currently planned to be 1,500 to 2,500 feet below the surface. Plans for the
gas injection wells will be reviewed by the State of Hawaii Department of
Health and the county of Hawaii and will comply with health and safety
regulations and permit conditions. As with the liquid injection well, the gas
injector will be steel-cased and cemented from the wellhead to the injection
zone, and drilling permits will be obtained from DLNR. Depending upon
reservoir management analysis and experience, the option of injecting the gas

into the liquid injection zone, 4,000 to 7,000 feet below the surface, may be utilized.

Monitoring Wells

The monitoring plan is currently under development. Preliminary plans include three slim monitoring wells, which will be drilled and cased to the gas injection zone, 1,500 to 2,500 feet below the surface. These wells will surround the gas injection well. Water samples will be periodically taken from the monitoring wells and analyzed to ensure that no adverse effects are resulting from gas injection.

2.3 WELLFIELD SURFACE FACILITIES

Wellpads

Up to three production wellpads and one injection wellpad, in addition to existing wellpads A and B, are currently anticipated over the life of the project. Additional wellpad sites will be selected on the basis of reservoir extent, optimal drilling targets, the expected reach of directional drilling, and specific site elevation as a protection against lava inundation. The three proposed additional wellpads shown in Figure 2-2 were selected by current knowledge of these criteria. As additional geophysical, drilling, and production information becomes available, the locations may be revised to obtain optimal performance. Drill sites will be constructed when needed. The additional wellpads will measure approximately 400 by 300 feet; each will accommodate up to four production wells.

Wellheads, in 10 by 10 by 14-foot cellars, will be placed about 30-50 feet apart to optimize pad space usage. Each wellpad will have one unlined, fluid collection sump (125 by 40 by 20 feet). In addition, each wellpad will accommodate a rock muffler for occasional flow testing, a fluid separator to split total wellsite production into steam and brine fractions, and adequate room to access each wellhead for future workover/redrill operations.

Steam Gathering System

Wellhead Piping Subsystem. A wellhead piping subsystem on each wellpad will control production from each well, as shown in Figure 2-3. Each wellpad will

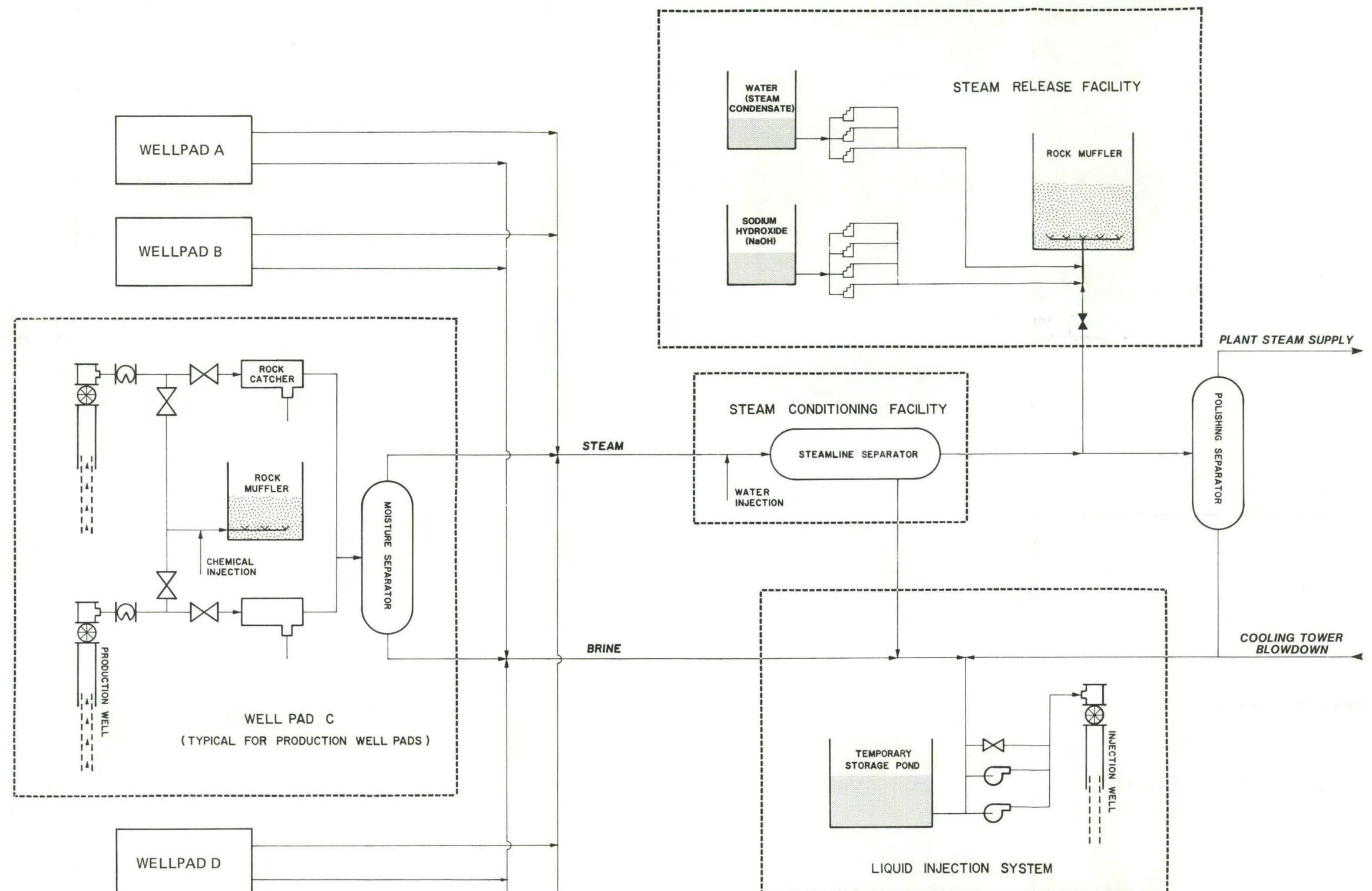


Figure 2-3
FLUID HANDLING
SYSTEMS

[illegible]

have a moisture separator to separate the steam and brine and deliver each fraction to the respective collection and transport piping. The subsystem will begin downstream of the master shutoff valve at each wellhead and will include production, throttling, and isolation valves; a flow rate metering run with orifice flanges; and instrumentation required for local or remote monitoring and control of each well. The system will be protected against overpressure damage with passive rupture disc safety devices, in accordance with the American National Standards Institute (ANSI) B31.1 Power Piping Code and applicable state regulations. A rock catcher (rock particle separator) will be installed immediately downstream of each wellhead. A rock-filled muffler will also be located on each wellpad.

Steam Collection and Transport Piping Subsystem. The wellhead piping subsystem on each wellpad discharges steam into the steam collection and transport piping subsystem. The pipeline is constructed of low-carbon steel, insulated and supported above ground. The size of the pipeline depends on the volume of steam to be transported, varying from a minimum of about 16 inches from each wellpad to about 24 inches for the main trunk line at the power plant inlet.

The pipeline supports will be steel pillars cemented in place and spaced about 30 feet apart, or as needed to prevent sagging. Generally, the pipeline will be 3 to 6 feet above the ground, but the actual height will be determined by the terrain and other pipeline design considerations. Periodically, expansion loops will be required to allow for thermal expansion of the pipe. These will be kept horizontal as much as possible; however, vertical loops may be required for situations like road crossings.

All piping that will operate under pressure will be designed in accordance with ANSI B31.1 Power Piping Code. The piping systems are engineered for stresses induced by thermal, pressure, dead loads, and seismic loads, taking into account all system operating conditions. Design of the piping supports, restraints, and anchors minimizes the induced stresses in the piping system. Sufficient horizontal and vertical flexibility are incorporated to withstand ground movements along the rift axis.

Steam transmission lines generally follow the shortest route from the wellpad to the power plant to minimize heat and friction losses. However, the layout of the pipeline system is dictated in part by the terrain of the area. For ease of maintenance and to minimize the extent of ground disturbance, steam lines will follow road alignments wherever practicable. They will also use a low profile design to reduce visual impacts as much as possible.

Experience at The Geysers geothermal field in California has proved that pipe fabricated from low-carbon steel is satisfactory for steam transmission lines, due to the low free oxygen content of the steam. Carbon steel steam transmission lines are also expected to be satisfactory in Hawaii for the same reason. Proper allowances will be made for corrosion and other forms of long-term degradation. Insulation and lagging, used to minimize heat losses, have proved to be effective in protecting external pipeline surfaces. A painted external surface that blends with background vegetation will be used to reduce visual impact. Vegetation will be encouraged wherever possible to further reduce visual impact.

Condensate Handling Subsystem. A condensate handling subsystem collects condensate that may form in the steam gathering system. The subsystem accepts the drains from the low points in the collection and transport piping and from the steam conditioning facility. The liquid condensate drains through 2-inch-diameter pressurized steel piping to the liquid injection system.

Steam Release Facility. The steam release facility releases steam to the atmosphere when the steam bypass system is not operational. In such an event, automatic admission control valves or safety rupture discs divert the steam to a two-cell rock muffler, located near the power plant. The cells are constructed of heat-resistant reinforced concrete and filled with lava rock to dissipate the steam's acoustic energy.

Steam entering the facility will be treated with injected sodium hydroxide (NaOH) to remove most of the H_2S . Storage tanks will be provided for the

chemicals, with flow being controlled with four 1/3-capacity NaOH injection pumps. Water will also be injected to desuperheat the steam so that the necessary chemical reaction can take place.

It is estimated that the steam release facility will be used approximately 260 hours per year during possible unscheduled outages of the steam bypass system, which could be caused by malfunctions in either the cooling system or the gas injection system.

Liquid injection is performed routinely at The Geysers in California and at other geothermal areas in the United States and around the world. Well in advance of plant operation, injection tests will be conducted at the project site to select the design injection pressure for the liquid injection pumps and to demonstrate liquid injection at the project site.

Steam Conditioning Facility. The steam conditioning facility will employ in-line systems to prepare the steam for delivery to the power plant. Such systems, which tend to be relatively simple in design, will be added on an as-needed basis. For example, injecting water into the steamline will have a scrubbing effect on the steam, which will remove silica, particulates, and other mineral carry-over from the wellpad separator. The injected water can then be separated, and clean, dry steam will be delivered to the power plant. The separated water will flow to the liquid injection facility.

Liquid Injection System

The brine separated from the steam flows from each wellpad in above-ground pipelines, generally parallel to the steam line, through a collection network to an injection well for injection into the geothermal reservoir. The pipeline is sized according to the expected volume of flow; it is insulated to maintain high temperature, thereby minimizing silica precipitation. Other liquids, such as cooling tower blowdown from the power plant, condensate drained from the steam pipelines, and wastewater from the steam conditioning facilities, are collected and transported through a separate pipeline to the injection wellpad. The total volume of fluids is anticipated to be on the

order of 280 gpm, but future wellfield development results will influence that quantity.

The fluids will be combined in a small, level-controlled, pressurized tank on the injection pad, where two full-capacity injection pumps will be available to drive the fluids into the reservoir. If the injection well or both pumps fail, a lined pond will be available for temporary storage. The exact location of the pond has yet to be determined.

2.4 POWER PLANT FACILITIES

The flow diagram for the power generation process for one of the two identical units is shown in Figure 2-4.

Turbine-Generator System

Steam Turbine. The two steam turbine units are standard industrial steam turbines with special material consideration to accommodate the geothermal steam. Each unit is designed to produce 12.5 MW (net) output, although operating conditions allow a degree of flexibility. Turbine control and isolation are provided by an electro-hydraulically operated control valve and stop valve in the main steam line, positioned just upstream of the turbine; fluid for the operation of these valves is supplied by the turbine lubricating oil system.

Lubricating oil is supplied to the turbine from ac motor-driven oil pumps and separate, redundant, lube oil coolers. The turbine shaft is sealed with main steam. From the turbine gland seals, the sealing steam is directed to the gland steam condenser. The condensate from the gland steam condenser is forwarded to the main condenser hotwells.

Generator. The two generator units are 3,600 rpm, 60 Hz machines, with a capacity of 14.7 MVA, a power factor of 0.85 lagging, and an output of 12.5 MW at 13.8 kV. These are directly coupled to the shafts of the main turbines, equipped with NEMA Class F field insulation and Type B stator insulation. The generators are inner-cooled by air, which is in turn cooled by water through

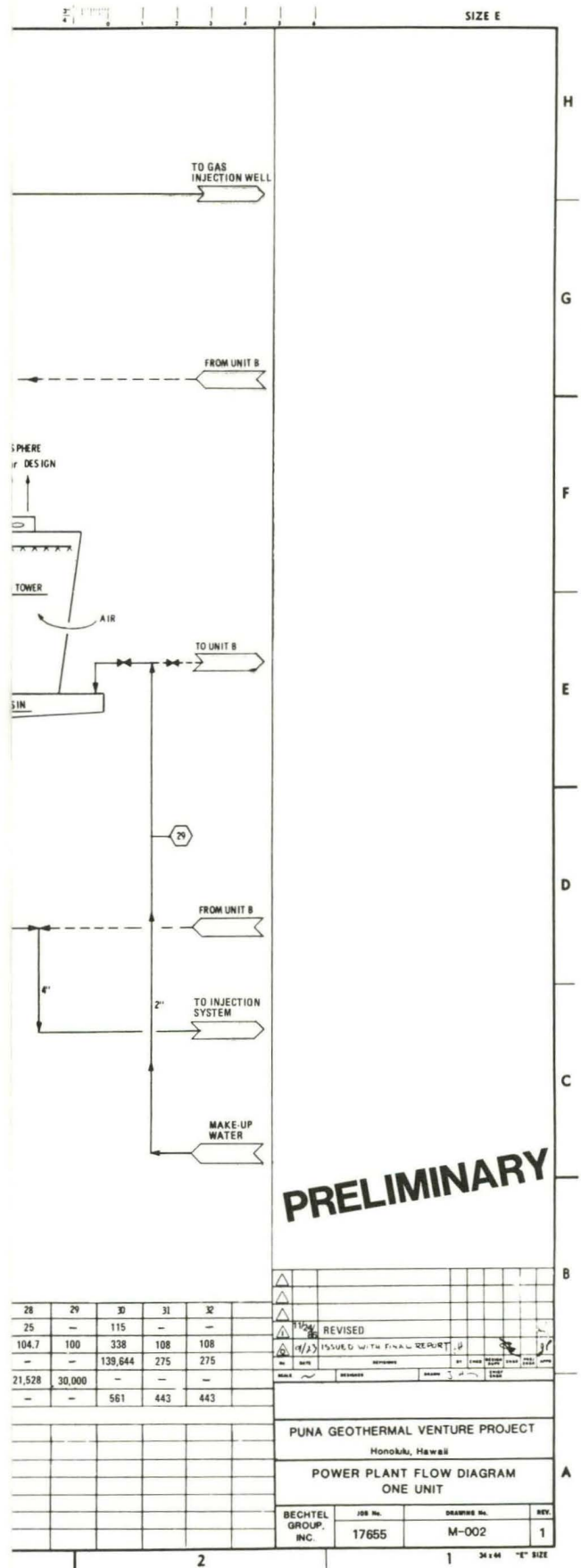


Figure 2-4 POWER PLANT FLOW DIAGRAM ONE UNIT

internal heat exchangers. Protective devices will guard against overcurrent, overvoltage, loss of field, and fluctuation in frequency. One three-pole 13.8 kV power circuit breaker serves each generator.

Condensing System

Condenser. Each steam turbine unit exhausts to a surface (shell-and-tube) condenser. At full turbine load with circulating water at the design inlet temperature of 85°F (29°C), the condensing pressure is about 3.0 in. HgA. The condensed exhaust steam is collected in the condenser hotwell.

Condensate Subsystem. Steam condensate is removed from each condenser hotwell by one of two full-capacity condensate pumps. Each unit requires one pump for normal operation; the other is on standby. These vertical can-type pumps are started and stopped by high- and low-level instrumentation in the hotwell; their discharge supplies makeup water to the circulating water system and the turbine bypass storage tank.

Instrumentation and control equipment associated with the condensing system trips the turbine-generator unit upon high- and low-condensate levels in the main condenser, high vibration or overcurrent on the condensate pump motors, and high condenser back-pressure. This is discussed further in Section 2.6.

Turbine Bypass Subsystem. Both generating units are designed with turbine bypass subsystems to bypass up to 100 percent of the plant inlet steam around the steam turbine to the condensers. The bypass steam is condensed, and the H₂S is handled as it is when the steam turbine is in operation. The turbine bypass system operates during plant startup, part-load operation, turbine-generator trip, and shutdown. Water for the bypass subsystem will be supplied from a storage tank, which is filled from rainwater and excess steam condensate.

Cooling System

The twin cooling towers dissipate heat to the environment by evaporating water circulated through them. Each tower cools approximately 21,000 gpm of circulating water from 105°F (41°C) to 85°F (29°C) when ambient temperatures are 94°F (34°C) dry bulb and 73°F (23°C) wet bulb. It is anticipated that these conditions will not be exceeded more than 2.5 percent of the time at the project site. Tower outlet temperatures, therefore, will be below 85°F (29°C) 97.5 percent of the time, and the main condenser pressure will be below 3 in. HgA 97.5 percent of the time. At design conditions, evaporation loss to the atmosphere will be approximately 380 gpm per tower. Design drift loss through the tower stacks is 0.002 percent of the circulating water flow, or less than 0.5 gpm for each generating unit.

Cooled water from the cooling tower collects in the tower basin and then flows to the circulating water pump structure. This structure is located at one corner of the cooling tower, and houses the pumps for both units. The circulating water pump for each unit discharges through a 36-inch diameter line, which carries water to the turbine building, through the condenser, and back to the cooling tower. Four 36-inch diameter lines run between the turbine building and the cooling tower.

Noncondensable Gas Removal System

Ejectors, using steam from the geothermal wells as motive fluid, remove the noncondensable gases entering the condenser with the exhaust steam from the turbine. This is a two-stage system with inter- and after-condensers cooled by water supplied from the circulating water system. The system contains two parallel units for each condenser, each capable of handling 50 percent of the design gas load. This allows ejector steam and cooling water consumption to be reduced if the quantity of gases is lower than the design value. Both sets of noncondensable gas removal equipment are used when main condenser vacuum cannot be maintained with one set.

Two lines from each condenser carry the noncondensable gases, along with some steam, to the two first-stage ejectors. The motive steam and

noncondensable gases from the first-stage ejectors are combined; the steam is condensed in the inter-condenser at a pressure of 7.5 in. HgA. The gases are removed from each inter-condenser by the two second-stage ejectors. The exhaust from the second-stage ejector condenses in an after-condenser at a pressure of 1 psig, and the noncondensable gases are routed to the gas injection facility.

Pollution Control Abatement Systems

The proposed abatement systems for the potential types of pollution (H_2S , solid wastes, process water, cooling tower drift, and noise) are described below.

H_2S . The H_2S that enters the power plant with the noncondensable gases in the geothermal steam is divided, or partitioned, into two streams in the main condenser. More than 98 percent of the H_2S is anticipated to exit the condenser with the other noncondensable gases; the remainder ^(2%) exits the condenser dissolved in the steam condensate. This magnitude of partitioning has been experienced in flow tests of wells on the project site. It is also obtained at the HGP-A power plant, which utilizes a well that produces steam with chemical composition similar to wells on the project site.

The noncondensable gas stream is supplied under pressure to a gas injection well for disposal in a nonreservoir rock strata. The zone currently under consideration for this purpose is just above the reservoir cap rock; there the injected gases would combine with H_2S naturally leaking from the reservoir into the nonpotable aquifer in this intermediate depth zone, as shown in Figure 2-1. The small volume of noncondensable gas (1,000 lb/hr) involved is easily soluble in the volume and chemistry of the existing brackish aquifer; natural scrubbing is expected to prevent any release of H_2S to the environment.

Two 100 percent capacity compressors, designed for sour gas service, compress the noncondensable gases for injection. In the unlikely event that both compressors are inoperable or the gas injection well requires

maintenance, the gas flow is diverted to the liquid injection system where the fluids are combined for injection directly into the reservoir. An emergency system, consisting of a scrubbing tower with sodium hydroxide (NaOH) scrubbing, will also be available. If none of the systems are functioning, the power plant shuts down and steam diverts to the steam release facility for abatement by chemical means.

If abatement of the less than 2 percent of the H_2S that is dissolved in the condensate is necessary to meet H_2S emission requirements, NaOH will be injected into the condensate to abate the H_2S .

(If the Dow system is unable to control the H_2S emissions, the RT-2 system would be used to abate the H_2S .)
Should the noncondensable gas injection system be unable to control H_2S emissions adequately, the RT-2 system developed by Dow would be used to abate the H_2S . In this system, the noncondensable gases are thermally oxidized (incinerated) and scrubbed with NaOH. The condensate is then treated with a regenerative iron compound. The two fluid streams are combined to produce environmentally acceptable sulfate and sulfite compounds that are dissolved in the condensate and injected at the geothermal reservoir depth with the cooling tower blowdown. Injection also minimizes waste stream disposal and handling. This system represents the state-of-the-art in surface chemical treatment of H_2S from geothermal resources, and a form of this technology is in use at the HGP-A power plant.

Gas injection is planned for the 25 MW geothermal power plant that is currently under construction at Coso, California. Prior to the beginning of construction, gas injection was demonstrated at the Coso site. A program to demonstrate gas injection will also be carried out at the PGV project site. This program will be performed in advance of the start of construction to select the design pressure for the gas injection compressors. The results of this program will also give an early indication regarding the need to install the Dow RT-2 incineration process for H_2S abatement.

Solid Wastes. Sludge that accumulates in the cooling tower basins is periodically removed and placed in a wellpad sump for evaporation. The solids that remain will be periodically covered with soil.

(will be covered with soil to prevent odors?)

Process Water. The process water consists principally of the brine fraction of the produced geothermal fluid and the cooling tower blowdown. Lesser amounts come from the plant drainage system, the wellfield condensate handling system, and the steam conditioning facility. The collected liquids are pumped into the injection well along with the cooling tower blowdown. Disposal by injection removes any need to discharge the process water to the surface. The average injection flow rate during normal plant operation is about 280 gpm.

Cooling Tower Drift. The water droplets making up the cooling tower drift contain dissolved solids and noncondensable gases in the same low concentrations as the circulating water. The design of the cooling tower limits the drift loss to less than 0.002 percent of the circulating water flow, which is less than 0.5 gpm for each generating unit. This drift has a maximum of about 400 ppm TDS. It evaporates in the air or falls to earth within a few hundred yards of the cooling tower, where it either evaporates or percolates into the ground.

Noise. Numerous noise abatement measures are included in the project design. Steam handling equipment, steam piping, and steam ejector housings will be insulated. Waste steam will be directed to the condenser via the turbine bypass system. If atmospheric discharge of the steam is required, it will be made through an effective rock muffler system. A low-noise enclosure for the operators will be provided inside the turbine building. An enclosed building will house the air compressors, which will reduce the amount of noise escaping to the outside environment. Ancillary equipment will be quieted as feasible.

Electrical Systems

Major electrical equipment includes the main power, auxiliary, station service, and current and potential transformers; generator circuit breakers; 4,160-volt switchgear; 480-volt load centers; 480-volt motor control centers; station batteries; and an emergency generator.

Each generating unit has a forced-air, air-cooled, three-phase main power transformer to step up the 13.8 kV generator voltage level to the 69 kV

transmission level, and reduce off-site power to 13.8 kV for auxiliary loads when the generators are not operating. An auxiliary transformer in each unit reduces the 13.8 kV generator output voltage to 4.16 kV, supplying power to the circulating water pumps and station auxiliary transformers. The station service transformers further reduce the 4.16 kV to 480 V buses for in-plant use.

Switchgear at the 4,160-volt/480-volt load centers and 480-volt motor control centers are designed to meet in-plant electrical requirements.

An emergency diesel-generator unit produces 175 kWe of 480 V power for essential electrical services if the system power fails. There is sufficient capacity to support one fire pump, one air compressor, the battery chargers, the HVAC system, and emergency lighting.

Auxiliary Systems

Auxiliary power plant systems include the compressed air system, service water system, makeup water system, fire protection system, and the heating, ventilation, and air conditioning (HVAC) system.

Compressed Air System. Compressed air is required for instrumentation, control, and plant maintenance (service air) requirements. The compressed air is distributed throughout the plant at 100 psig from a central compression system that includes reciprocating compressors, desiccant-type dryers, and dry-air storage tanks.

Service Water System. Service water is required for drinking and sanitary uses. Normal usage during operation is estimated at 200 gpd. A water line will supply potable water from the county water main. Emergency showers and eyewash stations using this potable water are provided in the primary and secondary H₂S abatement areas.

Makeup Water System. A rain catchment-water storage system will be employed to collect the water supply necessary for turbine bypass conditions.

Additional supplements from the condensate blowdown and the trucked-in water should meet the requirements of bypass operations.

Fire Protection System. The fire protection system is designed in accordance with National Fire Protection Association standards, and includes the following:

- o Fire protection water supplies, pumps and controllers, yard mains, hydrants, and valves
- o An automatic wet pipe and fusible link sprinkler system over the operating bay and storage areas
- o Automatic wet pipe, fusible link sprinkler systems at the turbine lube-oil reservoirs, diesel generator fuel tank, cooling tower, and oil-containing areas of the switchyard
- o A wetdown system at the cooling tower
- o Portable Halon extinguishers in the control room with backup water hoses

The cooling tower basin is the primary source of water for fire suppression. Each of the two basin sections stores 125,000 gallons of water. Two full-capacity fire pumps rated at 1,000 gpm at a 280 ft TDH for the entire plant are available. Both pumps are electrically driven, with emergency power for one pump available from the plant diesel-generator. The water loops around the plant provide main coverage for all buildings and enclosures. Hose stations are positioned approximately every 250 feet in the yard, and every 50 feet in the main bay of the turbine building.

The control room, motor control center, and electrical rooms are protected by a low-pressure CO₂ fire extinguishing system. These rooms are not normally occupied by operating personnel. CO₂ has been selected for fire extinguishing in these areas to prevent water damage to the equipment; water hoses are supplied in the event that the CO₂ fails to extinguish the fire. Portable Halon extinguishers are also provided in the control room.

HVAC System. Air conditioning is provided for the electrical equipment and control rooms. The system will be designed to prevent heat buildup and

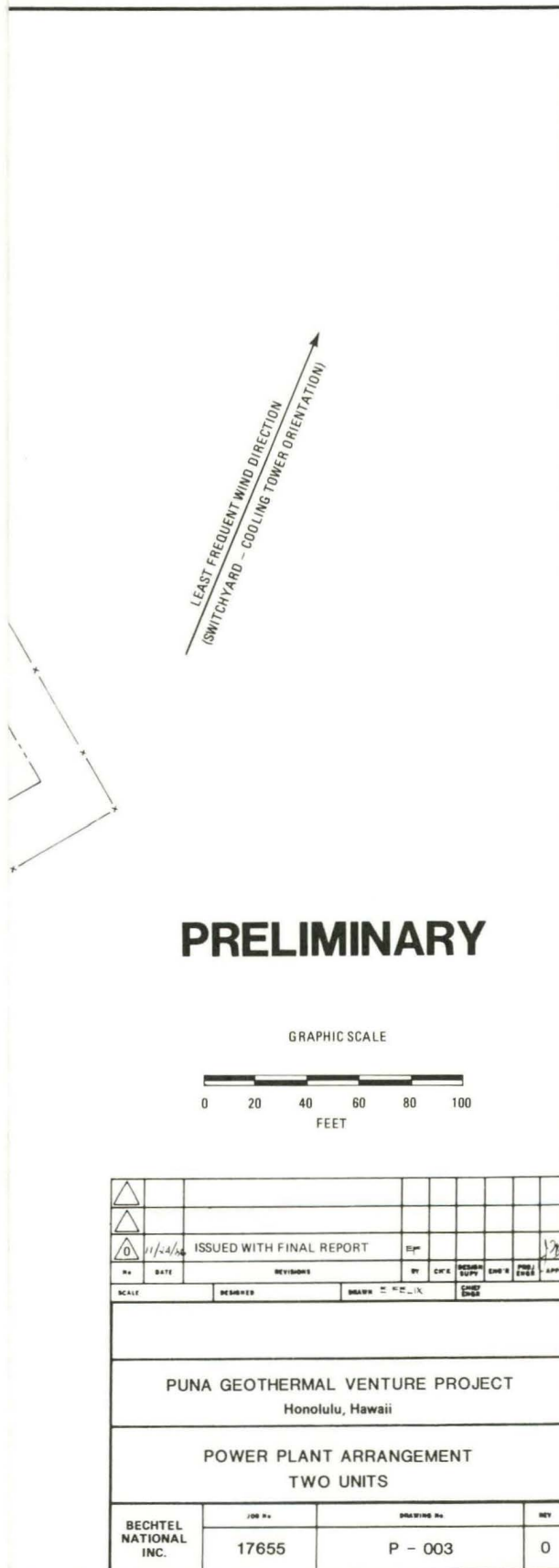
maintain a positive pressure in the rooms. This prevents contamination by any H_2S in the ambient air, which might affect electric circuits. The air conditioning unit includes a sealed refrigeration system and coil, outside air supply duct (including dust and H_2S filters), and an air distribution fan. The remainder of the turbine-generator building is cooled by three roof-mounted, motor-driven ventilators.

Power Plant Structures

The power plant will be designed and built using modular construction methods. The exact location and dimensions of the structures required for the power plant will not be known until the design of the facility is made final. The preliminary design indicates three main structures, i.e., the main turbine generator building and two adjacent cooling towers, occupying the site, as shown in Figure 2-5. There are also several smaller structures, including an administration building, control building, machine shop, warehouse facilities, transformers, and chemical tanks.

Power Plant Site Selection. The final layout of the power plant site will be determined prior to construction, with designs submitted to the county for approval. A preferred site has been selected, based on the evaluation of factors such as atmospheric dispersion of allowable H_2S emissions, visual impacts, land disturbance, topography, noise impacts, accessibility, protection from lava flow, geology, and relative position to the proposed wellfield development. This location is an area of approximately 5 acres along the southwestern flank of Pu'u Honua'ula, shown in Figure 2-2.

Buildings. The turbine-generator building, shown in Figures 2-6 and 2-7, is the largest structure on site, approximately 73 feet wide by 143 feet long. The height will vary according to the requirements of that area of the plant. The highest point is in the main turbine bay, where the need for an overhead crane requires at least a 30-foot ceiling; the condenser bay is closer to 15 feet high. The structural steel side walls and roof framing are covered with aluminum siding and roofing.



PRELIMINARY

GRAPHIC SCALE



	11/24/84	ISSUED WITH FINAL REPORT				ELP				
BY	DATE	REVISIONS	BY	CHK'D	DESIGN SUPP	ENG'R	PRO ENGR	APPR		
SCALE		DESIGNED		DRAWN		CHECKED				
PUNA GEOTHERMAL VENTURE PROJECT Honolulu, Hawaii										
POWER PLANT ARRANGEMENT TWO UNITS										
BECHTEL NATIONAL INC.		JOB NO. 17655	DRAWING NO. P - 003				KEY 0			

17 x 22 "C" SIZE

Figure 2-5 POWER PLANT ARRANGEMENT TWO UNITS

DOOR

GROUND LEVEL

1'-6"

PRELIMINARY

GROUND LEVEL

15'-0"

1'-6"

△									
△									
0	11	ISSUED WITH FINAL REPORT	REV						
DATE	REVISIONS	BY	CHK'D	DESIGN	DATE	APPROV			
SCALE	DESIGNED	DRIVEN	EF						
PUNA GEOTHERMAL VENTURE PROJECT Honolulu, Hawaii									
TURBINE BUILDING & COOLING TOWER ELEVATIONS TWO UNITS									
BECHTEL NATIONAL INC.	JOB NO. 17655	DESIGNING NO. P - 005	REV 0						

17 x 22 "C" SIZE

Figure 2-7 TURBINE BUILDING AND COOLING TOWER ELEVATIONS TWO UNITS

The control building is adjacent to the turbine-generator building. It contains the control room, electrical room, emergency diesel-generator, battery room, office, and lavatory.

A single-story administration building with about 2,000 sq ft of office space is located adjacent to the main entrance road to facilitate control of site access.

Structural Design. All building structures are steel frame construction; these structures and major equipment rest on reinforced-concrete footings. Minor equipment is placed on floors or mounted on walls. Anchors, sized to meet the appropriate load requirements, will secure all equipment to foundations, mounting pads, or surfaces. All structures, foundations, and footings are designed to support all applicable loads.

Foundation Design. A slab foundation will be provided for the turbine-generator building, with footings for each column. The turbine-generators will be supported on a reinforced-concrete pedestal that sits within this slab, and the main condensers each will sit on six footings. The outdoor electrical transformers will be mounted on concrete foundations, surrounded by dikes to contain any spillage. Concrete fire walls, with a 3-hour rating, will stand between the transformers and the turbine building.

Cooling Towers. Cooling towers are positioned to maximize access to wind flow, thus diluting both thermal discharges and H_2S emissions with a large volume of air. The current design, shown in Figures 2-6 and 2-7, envisions having one tower for each of the two generating units, with preliminary dimensions of 75 feet long by 73 feet wide by 40 feet high. Each tower is a two-cell mechanical induced-draft unit. A 6-foot-deep reinforced-concrete basin, lined with a coal tar epoxy compound as a protective coating, lies below each structure. On warm summer days, the plumes from the cooling towers are not expected to be visible. However, on cool days with high humidity, the water vapor emitted from the towers will tend to condense, creating visible white plumes, as described in Section 10.

Circulating Water Pump Intake Structure. The circulating water pump intake structure will be located on one side of the cooling tower basin. Each unit will have a full-capacity pump, and there will be a common standby. Two fire-fighting water pumps can draw water from either basin section.

Site Drainage

The high porosity of the volcanic soils in the site area ensures rapid percolation of rainwater, with insignificant runoff. In areas where chemicals are handled, concrete pads and berms will be provided to contain possible spills. Where necessary, catch basins, culverts, ditches, and berms will be provided for drainage control.

Roads and Fencing

Wherever practical, existing roads will be upgraded as needed to provide access to the project facilities. Primary access to the site will be afforded by the existing farm road off Highway 132, and a secondary entrance will be afforded by the current entrance on Pahoa Pohoiki Road. Both access roads will be engineered and upgraded to handle construction and operation needs. Before the roads are constructed, final engineering plans will be provided to the county and DLNR.

Six-foot-high chain-link fencing, topped with barbed wire, will be installed around the power plant boundary and each of the wellpads. A gate at each entrance to the site will restrict unauthorized access.

Construction Yard

A temporary construction yard of about 5 acres will be located next to the main entrance road to the plant, off Highway 132, as shown in Figure 2-2. The yard will be fenced.

Helicopter Pad

A helicopter landing pad will be located next to the main entrance road to the plant, as shown in Figure 2-2. It will facilitate the emergency transportation of any injured personnel to the hospital in Hilo.

Hazard Mitigation

The East Rift Zone has two types of potential geologic hazards: volcanic and seismic. The risks posed to engineered structures and installations can be significantly mitigated by appropriate procedures in facility siting and design.

Potential volcanic hazards consist of lava eruptions, lava flows, ash falls, splatter falls, and their associated surface disruptions. The risk associated with these hazards has been greatly reduced by locating the plant site and wellsites on high ground, avoiding the low areas. Quickly constructed berms or blankets of volcanic cinders will be utilized to protect the lower wellpads and, if possible, key elements of pipelines.

Each wellhead will be protected from lava flow by filling the concrete cellar, which contains the master wellhead valve, with cinders.

Potential seismic hazards are generated by earthquakes and include ground motion, ground ruptures, and subsidence. The strength and duration of motion from the strongest projected earthquake that might impact the Puna project area can be mitigated by appropriate design. The power plant, including all mechanical equipment, is designed in accordance with the standards of Uniform Building Code (UBC) seismic zone 3, with mean horizontal acceleration, velocity, and displacement of 0.25 g, 25 cm/sec, and 10 centimeters, respectively. Buildings and other permanent structures will be oriented with their longest dimensions parallel to the axis of the rift. Ground cracking and ruptures will most likely be associated with volcanic activity. The mitigation procedures previously outlined will also minimize the effect of these types of ground failure.

Fluid pipelines are the most vulnerable to disruption from geologic hazards. Circumstances may preclude the effective actions required to minimize field disruptions. Under these abnormally extreme conditions, timely shutoff of the wells and power plant will take place, and pipeline damage will be repaired in the shortest practicable period of time. To further reduce risk and ensure timely warnings of impending geologic hazards, close

coordination is planned among the Hawaiian Volcano Observatory, the Hawaiian Institute of Geophysics, and TPC.

2.5 CONSTRUCTION

The development schedule for the wells, wellfield facilities, and power plant is shown in Figure 2-8. As indicated in the figure, the first 12.5 MW unit is scheduled to be in commercial operation by the end of 1989, and the second 12.5 MW unit by the end of 1991. To support these dates for commercial power production, permitting is scheduled to be completed by November 1987. Wellfield drilling and development is scheduled in two increments to support the two generating units.

Estimated peak employment at the site during construction is expected to be up to 100 persons. Construction work will be accomplished, to the extent practicable, by local contractors and the local labor force.

Cut-and-fill slopes, as well as any uncovered level areas, will be seeded or planted with native vegetation. At the end of construction, all temporary buildings will be removed from the site, the fence surrounding the construction yard will be removed, and surplus materials and waste will be removed.

2.6 OPERATION AND MAINTENANCE

Staffing and Schedule

Operation. The power plant and wellfield will operate continuously 7 days per week. Qualified operators will be on site whenever the plant is operating.

Maintenance. Routine maintenance is conducted by workers during the normal daytime work shift. If either of the plant's two units is out of service or operating at curtailed output, the work will be done 24 hours per day, 7 days per week, until full power output can be resumed. If both units are operating at approximately full power, the maintenance work will be done by one shift per day, 5 days per week.

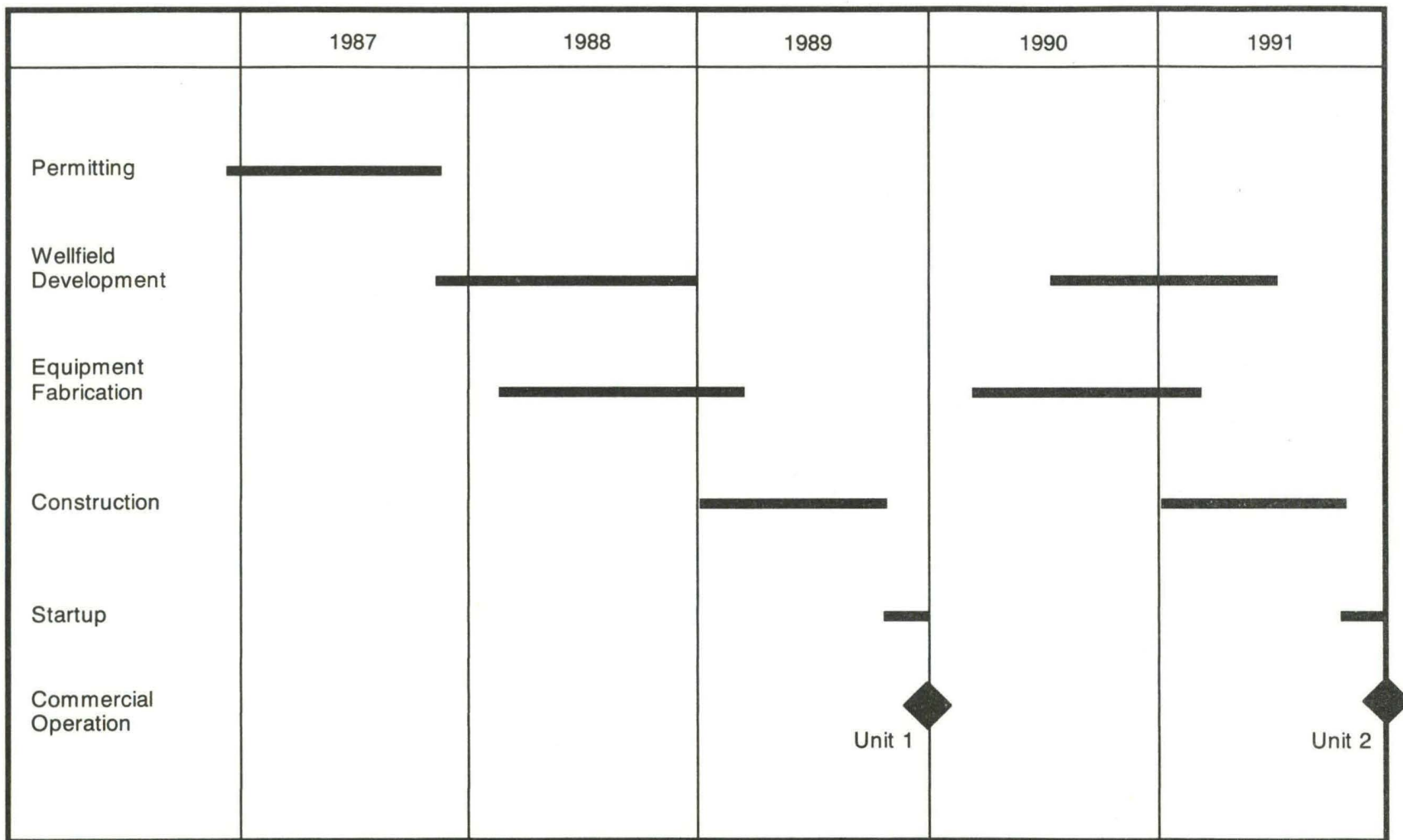


Figure 2-8 DEVELOPMENT SCHEDULE

*Can the well be shut-in as steam drives back to the
down release facility during the planned outages?*

Scheduled maintenance will be conducted for each generating unit at intervals of 1 to 2 years, as needed. During these planned outages, thorough maintenance procedures, such as turbine disassembly/inspection and condenser inspection/repair, will be conducted. These scheduled maintenance periods will require approximately 4 weeks for each unit and will be coordinated with HELCO to ensure the maintenance of a reliable power system. During this time, appropriately sized maintenance crews will be engaged around the clock, 7 days per week. Work crews will be rotated at 8- to 12-hour intervals.

Monitoring and Maintenance

Wellfield Monitoring. All wellheads will be equipped with local temperature and pressure gauges on the well casing below the master valves. Flow from each well is measured by an orifice flow meter in the line downstream of each control valve. Flow indication is local, and operation of the flow control valves is manual. The control valves at the steam release facility will have air-piston operators that respond automatically to signals from the plant control room or upon sensing overpressure in the steam pipeline. The H₂S abatement system at the steam release facility will operate automatically when steam is vented.

Continuous ambient air monitoring of H₂S will use the existing network of monitoring stations, as described in Section 6. Similarly, hydrological monitoring around the injection wells provides the means to ensure that no adverse effects result from injection. Portable noise measuring devices monitor noise from wellfield operations.

Wellfield Maintenance. Generally, wellfield maintenance will be performed without shutting off the flow of steam from any well. When this is not possible or safe, maintenance work for the wellfield will be phased so that the fewest possible number of wells are shut in and that wells are shut in for a minimum time.

Power Plant Monitoring. The power plant is designed for one-person operation. The plant operator performs prestart checks and manual valving, monitors the plant during operation, and periodically inspects the local

equipment. The two power plant units are operated from a single control room.

Control systems will operate automatically to prevent injuries to plant personnel or major equipment damage. During normal operations, standby equipment will start automatically to avoid tripping a turbine-generator unit. There will be an independent, self-contained control system for each generating unit.

Normal Startup and Shutdown

The turbine bypass system is used during plant startup and shutdown. When steam flow to the plant is initiated, it is routed through the bypass to the condenser. The gas removal and the gas injection systems are operational at this time. Flow is gradually increased and, once it is stabilized, the turbine-generator is brought on line. As the turbine-generator load is increased, the amount of steam bypassed is reduced until the bypass valves are closed. Plant shutdown is handled in a similar fashion, utilizing the bypass and turbine-generator in parallel until the turbine-generator is off line.

Turbine Generator Trip

The turbine bypass allows a full-load turbine trip without diverting flow to the steam release facility. Upon initiation by a turbine-generator trip device, the turbine bypass valve(s) open and main steam bypasses the turbine and proceeds directly to the condenser.

Each 12.5 MW unit can continue to handle full bypass flow for up to 24 hours while the cause of the trip is analyzed to determine the length of time needed for repair. If it is determined that corrective actions can be completed within a reasonable period, and the malfunction is not associated with any of the subsystems required for operation of the turbine bypass, the steam supply will be reduced and the bypass will continue to operate at this reduced flow rate. If a longer outage is required or the turbine bypass is not functional, the steam will be diverted to the steam release facility. The wellfield will be shut in only in the case of long-term outages. Shutting

down wells and returning them to service is generally minimized in geothermal operations around the world, because it can cause damage to the wells, which reduces their life. The cooling tower basin is sufficiently sized to allow for the negative water balance that could occur during the turbine bypass mode of operation.

Emergency Response Plan

An emergency preparedness plan for well drilling and testing has already been approved by the county and is in effect. It contains the details of procedures and chain of command that apply in the case of an emergency. Similar plans for construction and operation will be issued prior to the time they are needed, as described in Section 9.

2.7 DECOMMISSIONING

Plan for Decommissioning

When economic and resource conditions dictate that the power plant is to be decommissioned, the following steps will be taken to restore the site to an environmentally acceptable condition:

- o Structures and piping will be removed.
- o Dry or abandoned wells will be plugged with concrete, wellhead equipment and casing removed to below grade, well casing capped, and the surface restored.
- o Roadways will be abandoned to the extent agreed upon with the landowner.
- o The site will be regraded to approximate original contours, and the project area will be seeded or planted with natural vegetation.

Section 3
Land Use and Infrastructure

Section 3

LAND USE AND INFRASTRUCTURE

This section covers issues related to the compatibility of the proposed project with existing and future (to the extent known) land use. A discussion of infrastructure is also included.

3.1 ENVIRONMENTAL SETTING

Regional Land Use

The lower Puna District, where the project site is located, encompasses approximately 70 sq mi (see Figure 3-1). The boundary between the upper and lower portions of the Puna District is the line where small-lot subdivided land in upper Puna adjoins large-scale landholdings in lower Puna. The western portion of lower Puna, which is not shown in Figure 3-1, consists primarily of the Puna Forest Reserve and Hawaii Volcanoes National Park.

Uncultivated Vegetation. As shown by the existing land use data in Figure 3-1, most of the land in the lower Puna District is covered with "natural" (i.e., uncultivated) vegetation. This land includes essentially all of the areas within the State Conservation District (the Nanawale Forest Reserve, the Malama-Ki Forest Reserve, and the coastal area between Highway 137 and the shoreline). Natural vegetation is also the predominant cover type within areas depicted on the map as "urban residential, undeveloped" and "residential agriculture, undeveloped," but small parts of these areas have been cleared for roads and a few residences.

Agriculture. The next most extensive land use in the region is agricultural. Lumbering of the native ohia trees for the sawmill that operated in Pahoa between 1907 and 1918 resulted in cleared land, which was subsequently used for the cultivation of sugarcane. From the 1920s until the early 1980s, sugarcane remained the dominant crop in the region, and the Puna Sugar Company was the single largest employer. Sugar prices have remained at depressed

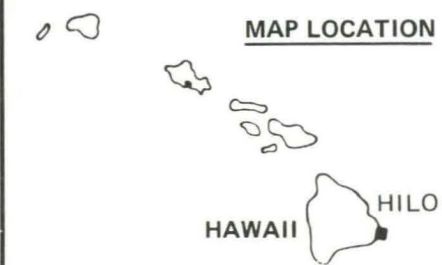
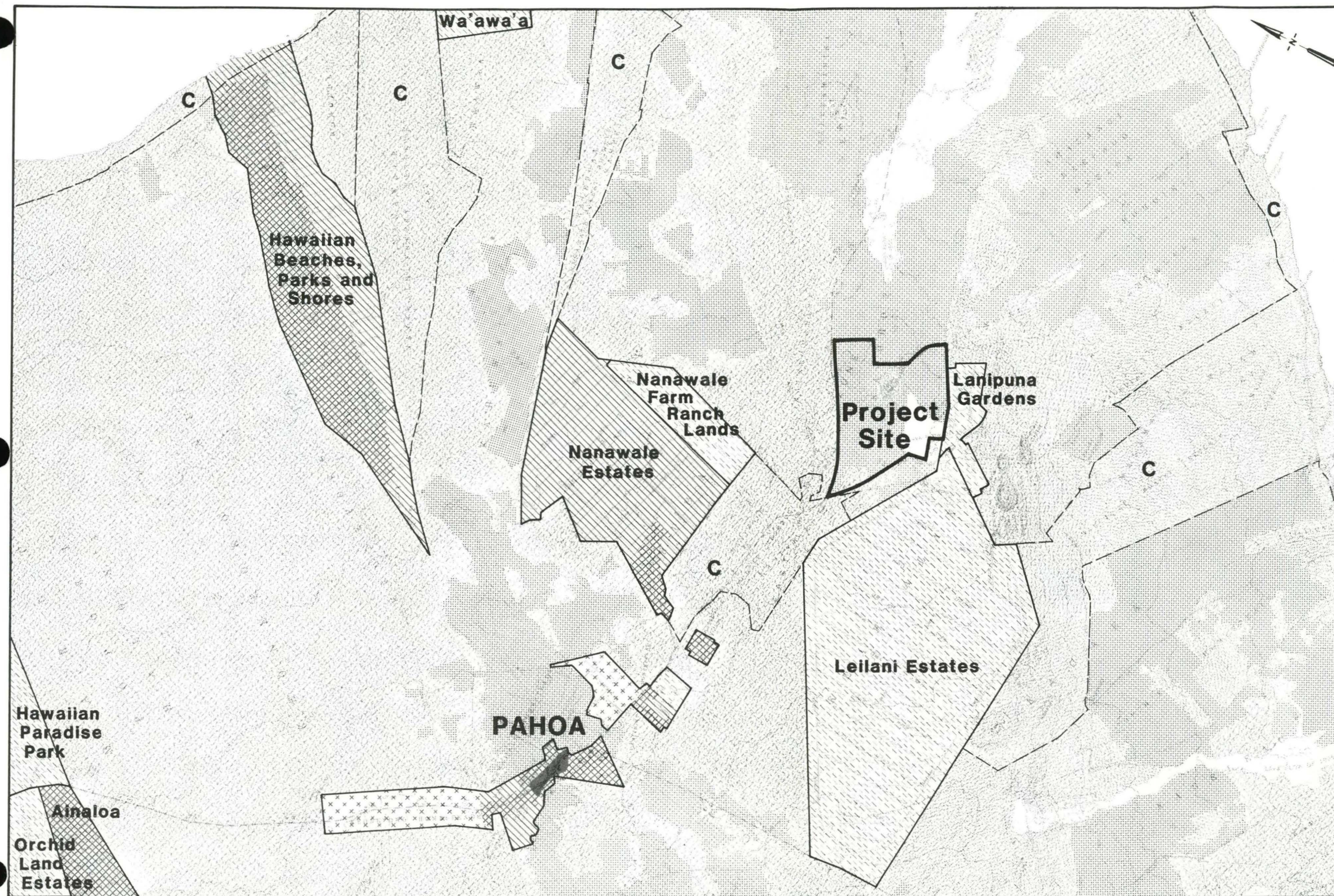
levels for some years, however, and in 1985, the Puna Sugar Company ceased operation.

With the closing of the Puna Sugar Company, papaya has become the principal agricultural crop. Acreage planted in papaya has steadily increased over the last few years as the Puna Sugar Company phased out its sugarcane production. The July 1986 total is approximately 8 percent higher than the July 1985 figure; the 1985-1986 growth rate in acreage is substantially higher than the increase during the preceding year, indicating continued health in the industry. Crop acreage figures are available only on an island-wide basis, but the Agricultural Statistics Service estimates that over 90 percent of Hawaii Island's papaya land (about 3,760 acres in 1986) is in Puna.

The pattern of papaya orchards changes from year to year. This is due to a combination of cultivation practices and a soil fungus that attacks young papaya seedlings. Because the papaya trees generally become too tall for efficient harvesting after 2 years, the practice is to cut the trees down and replant with seedlings. It does not become apparent whether the soil is infected until replanting, since the mature trees are not affected. The land can be used again for another planting of papaya if there is enough sterile soil with the seedlings (Jodar, 1984). The fungus is not as prevalent during relatively drier weather; apparently it does best in wet weather, which also makes spraying as a control more difficult and costly. Aerial photos indicate that about 500 of the acres leased by TPC are used for papaya orchards. When orchard land is abandoned, natural scrub vegetation quickly invades the land.

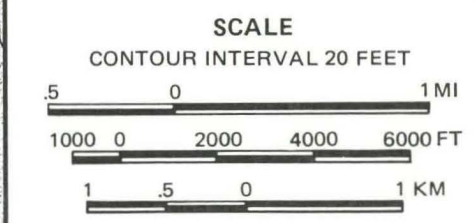
Some agricultural land in Puna is also devoted to other types of produce, cattle grazing, and flower cultivation. Scattered within the natural vegetation areas and, to a lesser extent, the sugarcane fields, are numerous small stands of marijuana. Marijuana is believed to occupy only a very small area of the Puna District. Nevertheless, the high value of this crop makes income from this source a significant factor in the local economy.

Residential Subdivisions. Large portions of the Puna District, especially upper Puna, were subdivided into residential lots during the late 1950s and



- LEGEND:**
- Urban Residential - Undeveloped
 - Urban Residential - Developed
 - Residential Agriculture - Undeveloped
 - Residential Agriculture - Developed
 - Commercial
 - Natural Vegetation
 - Cultivated Land
 - Recent Lava Flows
 - Conservation

BASED ON: State Land Use Commission District Map, Rev. Oct. 1982



SOURCE: U.S.G.S., 1980, 1981a, 1981b

**PUNA
GEOTHERMAL VENTURE PROJECT
HONOLULU, HAWAII**

**Figure 3-1
MAP OF THE
PUNA DISTRICT REGION**

BECHTEL GROUP INC.	JOB. NO.	DRAWING NO.	REV.
	15722		

early 1960s. The sections of the Ainaloa, Orchid Land Estates, and Hawaiian Paradise Park subdivisions visible in the northwest corner of Figure 3-1 are small parts of the more than 40,000 acres of subdivided land in upper Puna (Planning Commission, 1974). Closer to the site, about 6,000 acres are contained in the recent subdivisions and in the older settlements of Pahoa and Kaniahiku. The distinction made in Figure 3-1 between urban residential and residential agricultural subdivisions is based on lot sizes. The lots classified as residential/agricultural range in size from 1 to 5 acres. Areas shown on the figure as urban residential lots include those that have been subdivided into lots of less than 1 acre (most are between 8,000 and 20,000 sq ft in size). The determination of developed or undeveloped status was based on the density of structures shown on the three U.S. Geological Survey quadrangles (U.S. Department of the Interior, 1980, 1981) covering the area; these, in turn, were developed from aerial photos taken in 1977.

Most of the subdivisions in Puna were approved in the 1950s and early 1960s, prior to the enactment of the county of Hawaii's subdivision and zoning codes. Consequently, many do not conform to current standards for lot size and infrastructure improvements (roads, sewer, water supply, etc.). However, the right to develop has generally been "grandfathered," since the lots existed at the time the regulations were established.

Many of the old subdivisions that contain urban-sized parcels, i.e., lots smaller than 1 acre, are in the State Land Use Commission's Agriculture District. These include the Hawaiian Beaches, Hawaiian Parks, and Hawaiian Shores subdivisions. The county's zoning designation for these parcels, which by law must conform to the state's land use district designation, is also agriculture.

Portions of the recent urban residential subdivisions have been developed and are occupied primarily by residents commuting to work in Hilo. Most of the larger lots in the residential/agricultural subdivisions remain in their natural state. Profitable agricultural use generally is not feasible on these lots, given the lot sizes (1 to 5 acres) and conditions (heavily wooded and limited water supply). Moreover, a smaller lot is generally adequate and cheaper for residential use.

Recreational Land Use. Puna has many natural recreational areas. These include the Hawaii Volcanoes National Park and many beach parks, such as Harry K. Brown, Isaac Hale, McKenzie, Kaimu Beach, and the area around Queen's Bath. Tour buses frequently stop at the black sand beaches of Kaimu and Kalapana, but seldom stop at the other beach parks. Lava Tree State Park, less than a mile from the PGV project site, is also seldom disturbed by tourism.

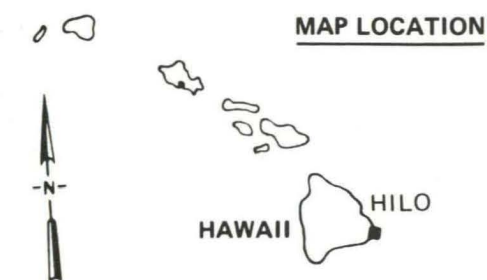
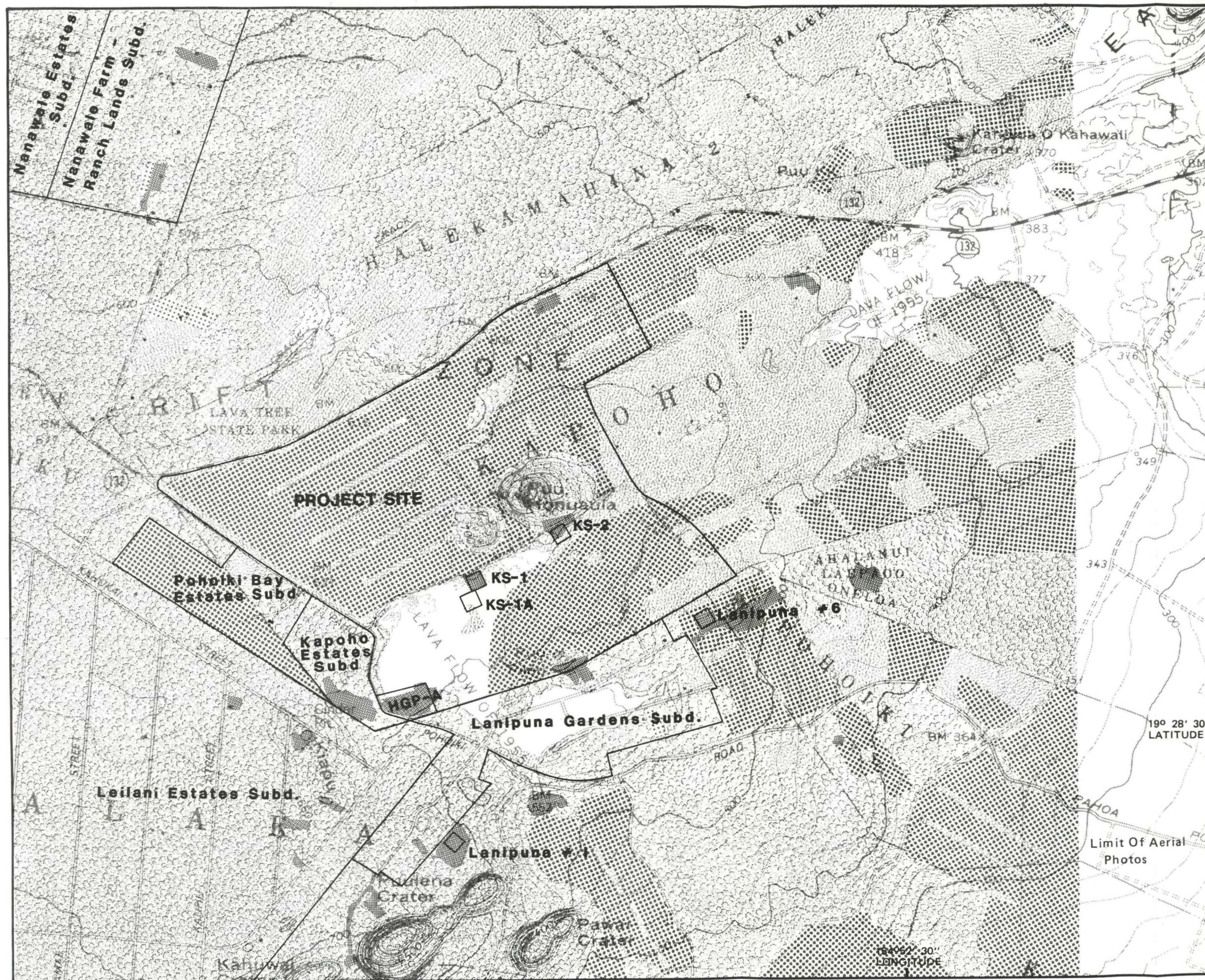
In the population centers, there are five ball parks or general public parks, playgrounds at Kea'au and Pahoa schools, and two gymnasiums open to the public (Canon, 1980).

Commercial Areas. The only commercial area within 5 miles of the project site is in Pahoa, and contains mostly restaurants and small shops. Major shopping centers are located outside the region in Kea'au and Hilo.

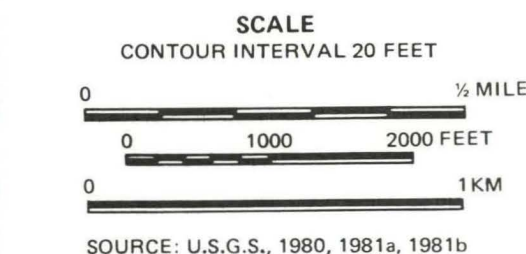
Land Use at and near the Site

The boundaries of the PGV project are shown in Figure 3-2. The various existing land uses on and near the PGV-controlled land, as well as subdivision boundaries, are also shown in this figure. The figure is based on aerial photographs taken by Air Survey Hawaii on March 8, 1984, and on field observations made in January 1984. Land cover categories depicted include recent lava flows, woodland vegetation, other natural vegetation, papaya orchards, other agricultural crops, and cleared land.

Residential development is limited in the immediate vicinity of the project site, although three subdivisions border part of the western and southern boundary of PGV land. The eastern portion of Lanipuna Gardens, to the south of the proposed power plant and well sites, has 89 lots, only three of which contain structures. Across Pohoiki Road to the west are the 10-lot Kapoho Estates and 14-lot Pohoiki Bay Estates subdivisions. All the lots are 1 acre in size except for one 18-acre and one 40-acre lot in the subdivisions to the west of Pohoiki Road; these larger lots could be subdivided at a later



- LEGEND**
- Woodland Vegetation
 - Other Natural Vegetation
 - Papaya Orchard
 - Recent Lava Flows
 - Cleared Land
 - Residential Structures/Other Buildings
 - Geothermal Wells



**PUNA
GEOTHERMAL VENTURE PROJECT
HONOLULU, HAWAII**

**Figure 3-2
LAND USE IN THE
PROJECT VICINITY**

BECHTEL GROUP INC.	JOB. NO.	DRAWING NO.	REV.
	15722		

date. The lots in these subdivisions are located 0.4 to 1.0 mile from the proposed power plant site.

The large subdivision of Leilani Estates, with 2,266 1-acre lots, is just to the west of the Kapoho Estates and Pohoiki Bay Estates. South of the Leilani Estates are 31 lots in the western portion of Lanipuna Gardens. Each is about 1 acre in size except for one 3.7-acre lot that encompasses a small hill. There is 1 mile or more between these subdivision lots and the power plant site.

Other nearby subdivisions include the Nanawale Farm Ranch Lands (also called Hawaiian Holiday Estates). The 88 lots in this subdivision are located about 1 mile north of the PGV lands and range in size from 1 to 5 acres. To the north of these is the Nanawale Estates subdivision with 4,289 urban-size lots of less than 10,000 sq ft (County of Hawaii, Planning Commission, 1967). There are currently no applications for approval of large-scale subdivisions in the vicinity of the project site.

The PGV project is within the Kapoho Geothermal Subzone as designated by the county of Hawaii. In addition to the PGV geothermal facilities, there are two other geothermal projects in the immediate vicinity. The state-owned HGP-A research and demonstration facility produces 3 MW of electricity. The power plant is operated under contract by HELCO, and its output is fed into HELCO's island-wide power grid. Lanipuna Well No. 6, drilled by Barnwell Geothermal Corporation, is located about 4,000 feet to the east of HGP-A. State records (Tagamori, 1984) show that this well was drilled to a depth of 5,000 feet, and that Lanipuna Well No. 1 was drilled to a depth of 8,000 feet; both wells are nonproductive and activity has been suspended.

Infrastructure

Roads. State Highway 11 is the primary Hilo-Puna-Kea'au route. The primary routes connecting lower Puna to Kea'au and Hilo are the Pahoa Road (Hawaii 130), the Kapoho Road (Hawaii 132), the Puna Coast Road (Hawaii 137), and a portion of the Chain of Craters Road. State Highway 11, the Chain of Craters

Road, the Kaimu Bypass Road, and most of the Kea'au to Pahoa Road are all-weather surfaced and in good to excellent condition. The others are in need of repair, widening, or other improvements (State of Hawaii, Department of Planning and Economic Development, 1982b, p. 3-24). Pohoiki Road, which currently serves the PGV site, is under county jurisdiction. Access to the PGV site during construction and operation of the project will be afforded by Highway 132 (Kapoho Road). A right-turn lane into the project area will be provided for traffic coming from Hilo and Pahoa to prevent any traffic impediment caused by vehicles turning into the project area.

State Route 130 (Kea'au-Pahoa Road) currently runs through the center of Pahoa Town. However, the State Department of Transportation has proposed construction of the Pahoa Bypass Road, which would carry through traffic around the heart of the existing urban area. The proposed bypass road begins about 1,000 feet north of Kahakai Boulevard and rejoins the existing alignment adjacent to Pahoa High and Elementary Schools. The new alignment is generally parallel to, and about 2,000 feet northeast of, the existing route.

Plans for the Pahoa Bypass Road call for it to have two 12-foot-wide traffic lanes and 8-foot shoulders. The design has been completed for some time, and right-of-way acquisition is currently under way. While the bypass project is relatively high on the State Department of Transportation's priority list, it has not yet been listed on the department's capital improvement budget, and construction funds have not been appropriated. If the 1987 State Legislature appropriates construction money, the improvements could be completed as early as the summer of 1988, but 1989 or 1990 is probably a better estimate of the earliest date the improvements could be in place.

Arterial roads and highways are adequate to handle the truck traffic associated with the various current agricultural endeavors. Improvements to Pohoiki Road may be required, however, if traffic from papaya and macadamia nut farms in the area increases. It is anticipated that "cane haul" roads will provide access, for future agriculture development, to lands once used for sugarcane; however, some of these roads may have to be upgraded. It is expected that roads of this type will continue to be privately owned and the responsibility of the landowner or the lessee.

Utilities. Telephone service is provided by the Hawaii Telephone Company; expansion is provided as demand requires. During construction, electrical power will be provided by HELCO, a subsidiary of the Hawaiian Electric Company (HECO). A 34.5 kV transmission line extends to within approximately 1 mile of the existing PGV wells. Power transmission is by overhead lines; the poles are shared with the telephone system.

During operation, on-site power requirements will normally be met using power generated at the plant itself. As an emergency backup, a 1.75 kWe generator producing 480-volt, three-phase, 60 Hz power will be available if the system power fails. This is sufficient to operate one fire pump, one air compressor, the battery chargers, the HVAC system and the emergency lighting. This generator will be driven by a diesel engine; enough fuel will be stored on site to operate the emergency generating system for at least 24 hours.

Power from the proposed 25 MW geothermal plant will feed into HELCO's island-wide grid through a new transmission line, which will be owned, constructed, and operated by HELCO. An environmental impact statement on this new transmission line is currently being prepared by HELCO and is expected to be completed in June 1987 (HELCO, 1987).

Water Supply and Distribution. The public water supply and distribution system is operated and maintained by the County Department of Water Supply. There are four major public water systems in the Puna District, one of which has been extended to the HGP-A well site. Project requirements are estimated at about 200 gpd from this system.

The municipal water supply on the island does not extend to all areas of Puna. Because most crops in Puna are not irrigated, extensions of this water system will not be required to support most of the agricultural activities predicted for the area. Flower and foliage products are an exception; in periods of drought, catchment may not provide sufficient water for these crops. Residents of areas without centralized water systems (including many in the Kapoho area, near the project site) rely on the roof catchment method for their supply. During periods of drought, the county assists these

families in replenishing their water supply. At such times, the county pays two-thirds of the cost of water (County of Hawaii, Planning Department, 1979, p. 33). Extensions of the county water system to current and future residents not served by the municipal system will be determined by the county in relation to its island-wide Capital Improvement Programs budget.

Disposal System. Municipal sewer systems are nonexistent in Puna. Sewage disposal in the district is by means of individual cesspools, septic tanks, or aerobic treatment units.

It is estimated that the proposed project would generate an average of less than 200 gallons of domestic wastewater per day. During short periods of scheduled and unscheduled maintenance activities, this could increase to as much as 1,600 gallons per day as a result of the increased on-site population. Current plans are to dispose of this wastewater by use of on-site cesspools. In view of the highly porous nature of the soils and underlying rock, these are expected to perform satisfactorily. No public drinking water sources would be affected by this disposal system.

3.2 ENVIRONMENTAL IMPACTS OF THE PROPOSED ACTION

Land Use Impacts

The project will use about 12 surface acres of the more than 10,000 acres controlled by PGV. None of the areas to be disturbed (for access roads, wellpads, and steam lines) is currently actively cultivated. Vegetation and other biological resources are discussed in Section 7.

New barriers created during construction may make access to certain parts of the orchard slightly more inconvenient for the papaya farmers. The steam line that could most affect farm equipment movement is the 1,500-foot line between the power plant site and the liquid injection wellpad. This inconvenience is unlikely to cause these portions of the papaya orchard to be abandoned.

There will be no direct impact on site land use except for the clearing and barriers discussed above. Noise and dust from construction operations may

impact nearby land uses. The extent of these impacts is discussed in Sections 6 and 8. Disturbed areas will be restored as near as reasonably possible to their original condition following facility shutdown.

Infrastructure Impacts

The infrastructure requirements for the Puna District, including community services, housing, and other facility requirements, are not expected to be significant (State of Hawaii, Department of Planning and Economic Development, 1982b, p. 7-10). Traffic through Pahoa will be increased during construction of the project, but it will be of limited duration and should not cause any significant congestion in Pahoa. If the currently proposed Pahoa Bypass Road is constructed before the start of construction on the PGV project, there should be no noticeable effects on Pahoa traffic at all. A right-turn lane for traffic coming from Hilo and Pahoa will be constructed at the entrance to the project area from Highway 132 (Kapoho Road).

During operation, the proposed project would add about 10 to 18 vehicle trips to existing traffic volumes. This amounts to a less than one-half percent increase over existing volume at the intersection of Highway 132 (Kapoho Road) and Highway 130 (Kea'au-Pahoa Road). This increase should not cause a significant impact on traffic in the project area.

Other access roads to the site may also need to be constructed, as indicated in Section 2 and in Figure 2-2. Water and sewage disposal is expected to be provided by the developer.

3.3 PROPOSED MITIGATION MEASURES

Land Use Impacts

To minimize the area affected by construction equipment and activities, the wellpads will be fenced as soon as grading is completed. All construction materials and equipment will be kept within these boundaries or on the internal roads.

To reduce any impacts of land clearing, the following measures will be taken:

- o Productive papaya orchard land will be avoided as much as possible.
- o Interference of construction traffic with papaya farmers' tractor roads will be avoided to the extent possible.
- o Access will be provided to papaya farmers through the pipeline layout area.

When cleared pad areas or pipeline corridors are no longer required, they will be promptly revegetated and restored.

The project layout is designed to minimize the amount of surface disturbance. Once the power plant and wells have reached the end of their 35-year economic life, the project site can be restored to its original agricultural land uses and natural vegetation, in accordance with the rules of the State of Hawaii Department of Natural Resources, Division of Water and Land Development (DOWALD). Revegetation of the portions of the pads located on the 1955 lava flow will accelerate the natural plant colonization of this generally unproductive land.

Impacts on surrounding land uses will be minimal. There is adequate area available on site to use as a staging area for the construction, so it is unlikely that off-site construction yards or bases will be required. A 5-acre temporary pad on site is currently planned.

The level of maintenance activity should not warrant the establishment of a maintenance base in the area and will not, therefore, contribute to that type of increased industrial activity in the area. Instead, firms performing the maintenance would almost certainly operate out of existing facilities in Hilo. Unscheduled maintenance would occur in the event of equipment failure and would involve intense activity 24 hours a day by moderately large (4- to 10-person) crews. These workers would be drawn from the skilled work force in Hilo, Oahu, and/or the mainland depending upon the nature of the problem. No new off-site industrial base would be supported by this type of intermittent activity. Scheduled maintenance would be carried out on the power plants at

1- to 2-year intervals. During these planned outages, major maintenance activities (e.g., turbine disassembly/inspection and condenser tube inspection and repair) will be conducted. This would require relatively large teams of workers (10- to 20-person shifts) working round the clock for a period of approximately 4 weeks. Because of the intermittent and highly specialized nature of these activities, it is expected that nearly all of them would be performed by firms based outside Puna.

Infrastructure Impacts

No mitigation measures are needed.

Section 4
Geology

Section 4

GEOLOGY

4.1 ENVIRONMENTAL SETTING

This section describes the geology, soils, and seismic and volcanic risks of the project area, based on a review of published reports and maps (Moore, 1986; Moore, 1982; and Slemmons, et al, 1981).

Regional Geology

Surface Geology. The PGV 25 MW project is located within the lower East Rift Zone of Kilauea Volcano, as shown in Figure 4-1. Kilauea is one of the world's most active volcanoes, and the East Rift Zone is one of its conduits for the lateral migration of basaltic magma from the holding chamber beneath the volcano's summit caldera. The rift zone is manifested at the surface as a linear belt, 1 to 2 miles wide, consisting of linear and open fissures, faults, small grabens, pit craters, cones, and vents related to numerous volcano-tectonic events. In the lower East Rift Zone, volcanic eruptions have occurred as recently as 1740, 1840, 1955, 1960, and 1961. The rift is a constructional ridge some 150 to 1,500 ft (50 to 500 m) above the adjoining terrain throughout its length, except in its lowermost portion where the ridge disappears into a low-lying area consisting of a series of grabens and spatter deposits (Moore, 1983). This marked topographic change corresponds to a structural intersection of the east-northeast trending rift zone with a north-northwest trending transverse fault. Initial geothermal development activities will focus on this region.

Subsurface Geology. Underlying the surface expression of the East Rift Zone is a broad, 5- to 15-mile-wide (8 to 24 km) dike complex. This complex is thought to consist of an aggregate of closely spaced, parallel to subparallel, vertical to steeply dipping dikes whose top is generally 8,000 ft (2,500 m) below the surface. These dikes intrude a sequence of layered Mauna Loa and Kilauea lava flows. The complex is reported to be locally above 1,000°F

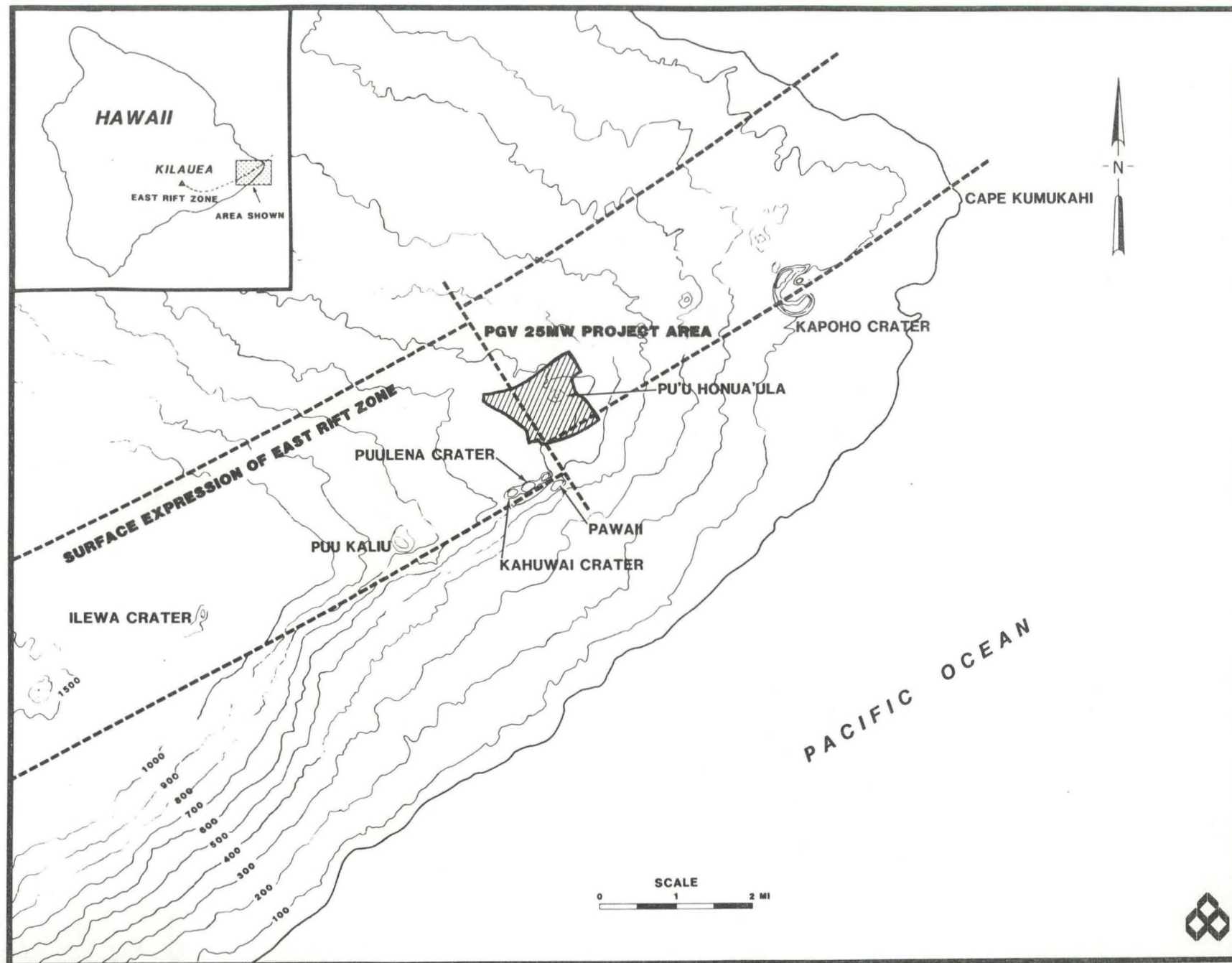


Figure 4-1 PROJECT LOCATION MAP

(540°C) and in places may even approach 1,900°F (1,000°C), the melting point of basalt (Furumoto, 1978). Chemical studies of the rift lavas suggest the existence of local magma chambers within the rift. The Puna geothermal system overlies such an area.

Local Geology and Soils. The project site is entirely underlain by basaltic aa and pahoehoe lava flows and associated ejecta of the Puna Volcanic Series, Historic and Prehistoric Members. Major eruptive features include Pu'u Honua'ula and Pu'u Pilau. Minor spatter and cinder cones associated with the lava flow events are common throughout the area.

Three eruptive events representative of the Prehistoric Member have occurred in the region of the project. The oldest include cinder and spatter cones of Kipu, which are estimated to have erupted 1,500 years before present (BP) or earlier. These features are located immediately to the southwest. Spatter cones and lava flows of the Pu'u Kii fissure are dated at approximately 750 to 1,000 years BP and are exposed northeast of the project site. To the south, the Pu'u Kii flows are overlain by flows from Pu'u Honua'ula, which erupted an estimated 500 to 700 years ago.

The Historic Member is represented by flows of the 1790 and 1955 eruption. In the southern Puna District, the 1790 flows erupted from fissure zones along both the northern and southern boundaries of the rift. The most recent lavas at the site erupted in 1955 from a discontinuous "en echelon" fissure system that longitudinally transects the project area. Flows from this event covered the southern portion of the project site (Moore, 1981; Moore, 1986).

Soils of the Keaukaha, Opihikao, and Malama series cover approximately 75 percent of the project site. Bare lava flows cover the remainder. The Keaukaha Soil Series is present in the western section, southwest of Pu'u Honua'ula. The soil is generally thin and ranges up to 8 in. (20 cm) deep and overlies pahoehoe lava bedrock. In representative profile, it is very dark brown and mucky with a moderate to fine subangular blocky structure. The soil is rapidly permeable and strongly acidic. Runoff is medium, and the erosion potential is slight. The Opihikao Soil Series, found in the western half of

the site, is the most predominant soil type. Thick organic soils, which are very permeable, constitute this series. In representative profile, the upper 3 in. (7.5 cm) is very dark brown, mucky, and friable with a medium to fine subangular blocky structure. The soil, which is strongly acidic with a slight erosion potential, overlies pahoehoe lava bedrock. The Malama Soil Series extends across the center of the site to the northeast of Pu'u Honua'ula. It consists of well-drained, extremely stony organic soils, ranging up to 1 ft (0.3 m) in thickness and underlain by aa lava flows. In representative profile, the upper 3 in. (7.5 cm) is very dark brown, contains extremely stony muck, and is underlain by fragmental aa lava. Because the soil has a high permeability, runoff is minimal and the erosion potential is slight. TPC is preparing a detailed map of the surface geology of the project site.

Geologic Hazards

Volcanic hazards on the island of Hawaii are greatest near Mauna Loa and Kilauea, and the risk is highest along the rift zones of these volcanoes. The volcanic hazards that can affect persons and property are categorized as either direct or indirect. Direct hazards are lava flows, falling rock fragments, drifting volcanic gases, and particle-and-gas clouds. Indirect hazards include ground movements such as subsidence, surface ruptures, earthquakes, and tsunamis. The zones of overall relative risk from volcanic hazards are presented in Figure 4-2. The project site lies within Kilauea's East Rift Zone and is characterized as an area that may be subject to high risk due to volcanic hazards (USGS, 1974).

The East Rift Zone has two types of potential geologic hazards: volcanic and seismic. The risk that these potential hazards pose to engineered structures and installations can be markedly mitigated by appropriate procedures in facility siting and design.

Potential volcanic hazards consist of lava flows and ash falls, splatter falls, and their associated surface disruptions. The risks associated with these hazards will be greatly reduced by locating the plant site and wellpads on high ground, avoiding low areas where lava is likely to be channeled. Wellpads in low areas, if threatened by lava flows, can be protected with

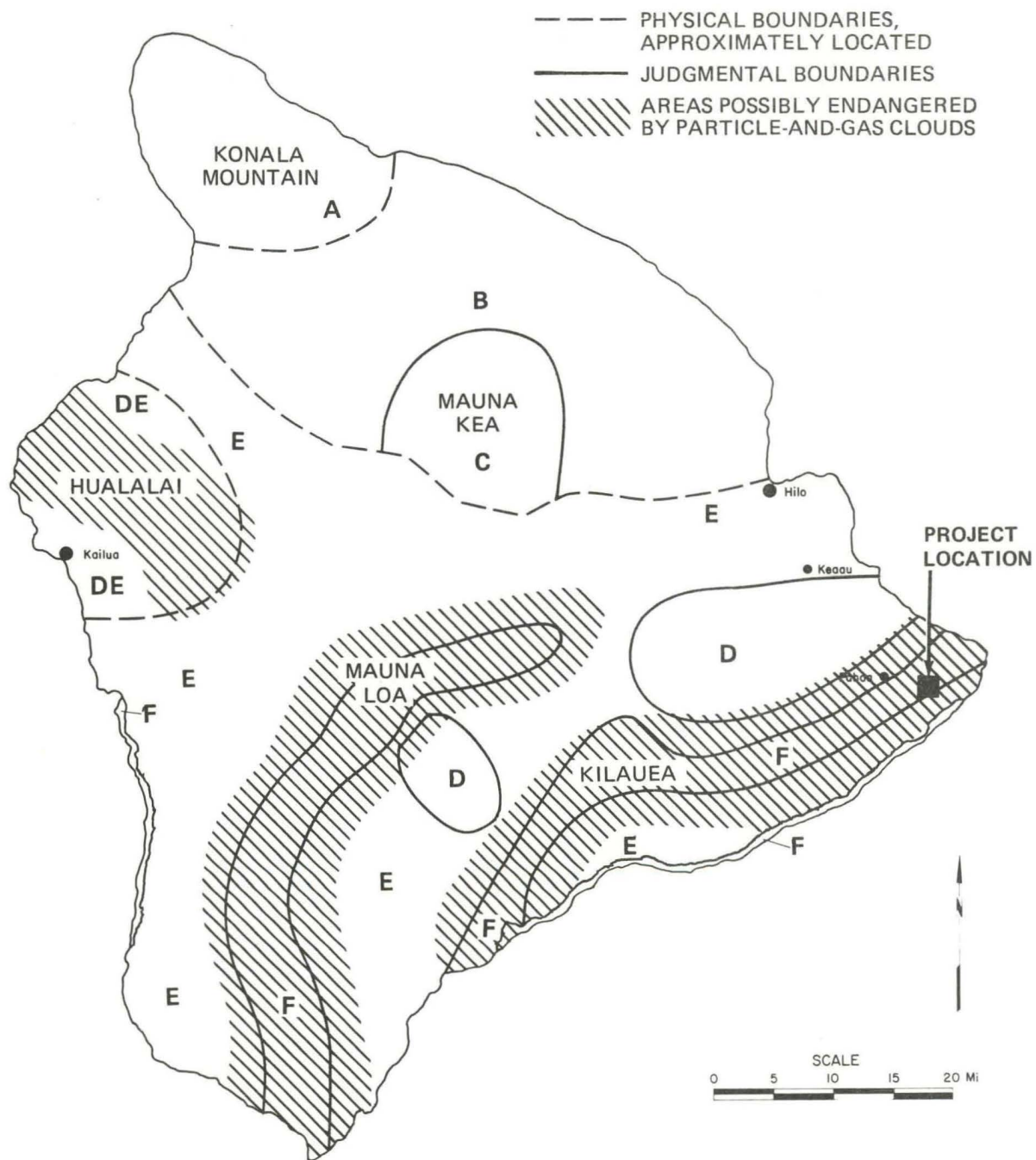


Figure 4-2 ZONES OF OVERALL RELATIVE RISK FROM VOLCANIC HAZARDS (RISK INCREASES FROM "A" THROUGH "F")

quickly constructed berms of volcanic cinders. Such diversion barriers should deflect flowing lava from the wellhead. Cinders can also be placed within the well cellars to prevent lava from encasing the wellhead.

Potential seismic hazards are ground motion from earthquakes, ground cracking or ruptures, and subsidence. The strength and duration of motion from the postulated strongest earthquake that will most likely affect the project site is within the range that can be readily mitigated by appropriate design. Buildings and other permanent structures will be oriented with their longest dimensions parallel to the axis of the rift. Ground cracking and ruptures will most likely be associated with volcanic activity. The mitigation procedures outlined above will also minimize the effect of these types of ground failure. Subsidence, deemed unlikely, should be a very slow process. Consequently, it is not considered a significant concern.

4.2 ENVIRONMENTAL IMPACTS OF THE PROPOSED ACTION

The primary geological impacts on the project site consist of two types. Construction impacts are impacts on the topography, surface geology, and soils associated with earthwork and excavation activities during the clearing and construction phase. Operation impacts are ground changes related to wellfield production and injection activity.

Construction Impacts

Some grading, grubbing, and stockpiling of soil, cinders, and rock will be required at the project site to support the planned activities. Such alterations will result in changes in surface drainage. However, the impact will be minimal because the ground alteration planned is limited and ground percolation rates are high.

Removal and disruption of soils during clearing and construction could result in changes to the soil structure, density, and moisture content. These changes could potentially increase erosion and alter groundwater percolation rates and vegetative support. However, these effects are considered negligible at the project site because the soils generally have rapid percolation rates and low susceptibility to erosion.

Operation Impacts

Evidence collected from geothermal developments worldwide shows some relationship between geothermal fluid production and injection, with increased seismicity and subsidence in certain producing regions.

Increased seismicity, when it does occur coincident with geothermal development, is of magnitudes less than 4.0 on the Richter scale. Such levels of seismicity are minor events compared to the November 1975 earthquake, of magnitude 7.2, the largest in recorded history of the southern Puna District (no damage was reported in the Pahoa and Kapoho areas). Seismic events, which are caused by changes in the hydrologic and tectonic balance in and around the geothermal reservoir, are not of a sufficient magnitude to cause significant surface damage. Thus, seismic effects are not considered an environmental concern for this project.

The dense, basaltic lava flows and dikes that make up the rock of the geothermal reservoir are self-supporting; the top of the reservoir is at a 4,000-foot depth. These factors make subsidence due to geothermal production very unlikely.

4.3 PROPOSED MITIGATION MEASURES

Grading activities during construction will cause minor surface changes within the project site. To maintain natural topography, these activities will be kept to a minimum. Construction vehicles will be limited to those areas under development to minimize soil disturbance. When possible, on-site materials will be used for fill to reduce the need for imported construction materials. Excess earth unsuitable for use in construction will be stockpiled and stabilized according to building regulations to avoid any increased erosion potential. The planned surface changes will result in insignificant impacts.

Fluid pipelines have the greatest vulnerability to disruption from geologic hazards. In such cases, judicious and timely on-site field evaluations are required to minimize wellfield disruptions and environmental

impacts. Under these extreme conditions, automatic shutoff of the wells and power plant will take place. Wellfield damage will be repaired in the shortest period of time possible. To further reduce risks and ensure timely warnings of impending geologic hazards, close coordination is planned between the Hawaiian Volcano Observatory, the Hawaiian Institute of Geophysics, and TPC.

Section 5

Hydrology

Section 5

HYDROLOGY

5.1 HYDROGEOLOGIC SETTING

Geothermal Resources

The Puna geothermal resource is a very high-temperature, two-phase, liquid dominated type of reservoir located in Kilauea's lower East Rift Zone. Such reservoir types are not common but do occur in young volcanic areas. The Tongonan Field in the Philippines and Los Azufres in Mexico are two examples. Within the Puna field, geothermal fluids associated with a major north-northwest trending transverse fault beneath the site are thought to migrate along vertical fractures within the rift zone.

The reservoir is believed to be maintained by a very high heat flow within the rift and by an effective seal that inhibits significant venting. It is confined to the rift except where faults allow extension into non-rift areas. Where the seal is locally broken, leakage of geothermal fluids occurs. This is indicated by the presence of geothermal waters both within the rift zone and south of the rift zone. Within the rift zone and immediately downgradient of the Puna field, there is no fresh groundwater.

The wellfield development plan includes disposing of brine through injection into the geothermal reservoir, and noncondensable gas and steam condensate within a nonpotable aquifer in the interval above the seal. Injection of geothermal fluids is performed routinely in the United States and other countries. For the last 50 or 60 years, oil field brines have been injected into subsurface formations, and today petroleum by-products are disposed of almost exclusively by injection. Injection is also used to dispose of industrial, domestic, and municipal materials. Injection wells are widely used as a secondary recovery technique in the petroleum industry. About 90,000 secondary injection wells and 30,000 disposal wells are believed

to exist in the United States (National Water Well Association, 1978). Much of this nongeothermal injection technology can be applied to the geothermal industry including well design, monitoring methods, and reservoir models.

Injection is by far the preferred method of disposing of geothermal liquid and gases. Other methods of geothermal fluid disposal have been conceived, and some have been tried. In most cases, the quantity and chemical composition of the fluids make alternatives environmentally unacceptable in the United States. Therefore, injection is the best method of geothermal liquid and gas disposal.

However, the effect of geothermal injection on the surface and groundwater must be understood to conduct a safe and effective injection operation. The following paragraphs describe regional surface water and groundwater hydrology; regional water quality; the potential effects of injection on the site surface and groundwater hydrology; and site water quality.

Regional Surface and Groundwater Hydrology

Perennial streams and rivers are not common on the island of Hawaii. The unweathered and highly permeable lavas and well-drained soils allow much of the rainfall to percolate to the water table. The surface runoff that does occur on the island fluctuates considerably with variations in rainfall. The largest streams are located on the northeast (windward) side of the island in areas of high rainfall. Streams in areas of moderate rainfall are perennial in their upper reaches, with flows reaching the coast only during periods of substantial rainfall.

There are no perennial streams in the Puna District; the largest intermittent stream in the district is located about 15 mi (24 km) north of the proposed project site, parallel to and just south of the Hawaii Belt Road.

Based on occurrence, potable groundwater on the island of Hawaii falls into three general categories:

1. Basal (fresh) water floating on salt water (Ghyben-Herzberg lens)

2. Water confined by dikes
3. Water perched on relatively impervious soil or rock formations

The Puna District, except for the area within the East Rift Zone, is underlain by predominantly basal water, as shown in Figure 5-1B. Within the East Rift Zone, the groundwater is impounded by a dike system that characterizes this rift feature, as shown in Figure 5-1A. Groundwater impounded by the dike system is at higher levels than the basal water outside the East Rift Zone. The dike-confined water within the East Rift Zone discharges to the basal supply through fractures that act as subsurface leaks. In areas where these leaks intersect the ground surface, the confined basal water discharges as springs.

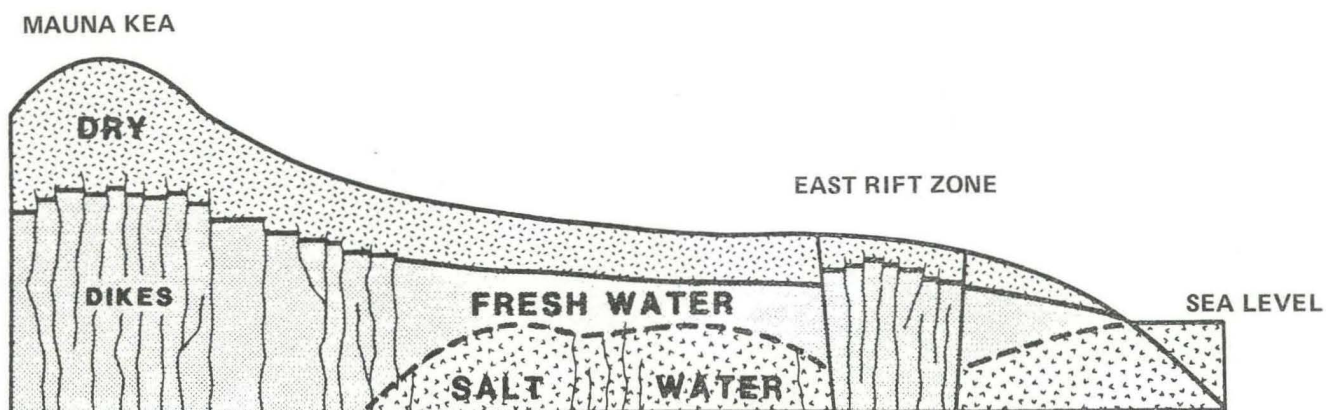
Regional Water Quality

Hawaii's groundwater quality is largely influenced by the surrounding sea. Unless the highly permeable water-bearing lava flows are capped by low-permeability rock or are cut by low-permeability dikes, the ocean may freely penetrate wherever an aquifer is exposed below sea level and fluid pressure gradients permit. The density difference between fresh and salt water allows migrating fresh groundwater to float on salt water. However, tidal fluctuations and other head variations tend to create a zone of mixing, which results in a transition zone between fresh and saline water. Because of these conditions, the TDS concentration of the groundwater varies significantly with location and depth.

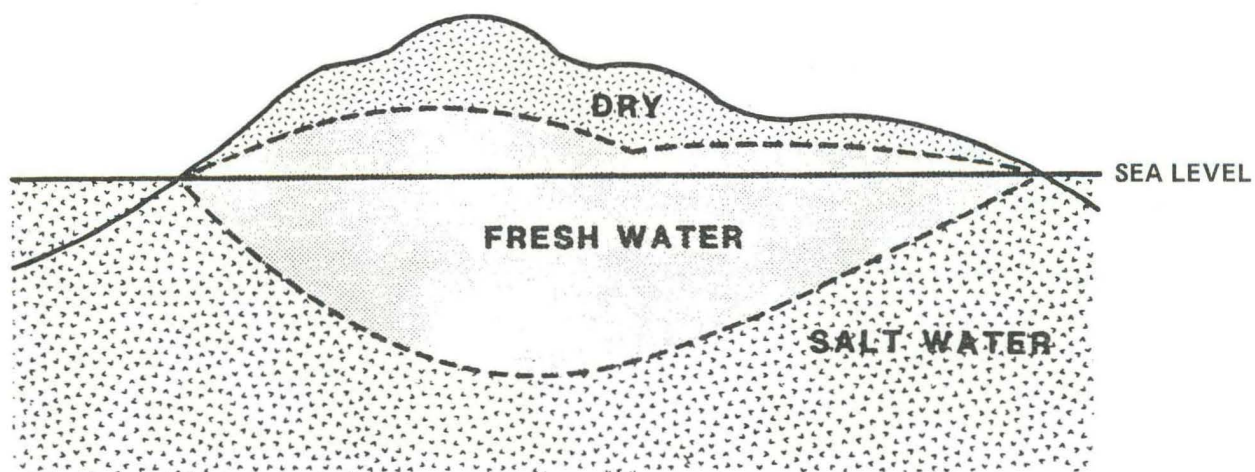
On Hawaii, inland water wells tap only the uppermost layer of the basal fresh water. The water from these wells has less than 150 mg/l TDS concentration. Near the coast, where wells reach the zone of seawater mixing, the groundwater is brackish to saline with TDS concentrations ranging from 1,000 to 10,300 mg/l.

Site Surface and Groundwater Hydrology

There are no surface water drainage courses either on the project site or anywhere in the lower Puna District. Rainfall percolates rapidly into the



A. Schematic cross-section from the rift zone of Mauna Kea through the East Rift Zone of Kilauea showing the distribution of fresh water and salt water (modified after Stearns and Macdonald, 1946). Two types of ground water occurrences are illustrated: dike-controlled and basal water within and outside the rift zone, respectively. Only two water chemical categories are shown.



B. The Ghyben-Herzberg Principle showing the lens of fresh (basal) water floating on salt water (modified after Stearns, 1966).

Figure 5-1 GENERALIZED MODEL OF THE GEOHYDROLOGIC SETTING OF THE EAST RIFT ZONE

well-drained soils and highly permeable lava flows. The recharge rate of the groundwater is high. About 114 in. (290 cm) of precipitation fall annually at the site, resulting in a recharge of about 6,080 acre-ft/yr/mi². Loss due to evapo-transpiration is estimated to be about 30 in. (75 cm), leaving about 4,440 acre-ft/yr/mi² to infiltrate to groundwater (Weiss Associates, 1983).

Based on the water's temperature and chemical characteristics, groundwater quality in the southeastern portion of the island of Hawaii has been classified by TPC (Iovenitti, 1986) into three basic types: fresh, geothermal, and mixed. This is shown in Figure 5-2. Fresh groundwater occurs north of the lower East Rift Zone and south of the rift in an area southwest of the project site. Geothermal groundwater is found (1) proximal to a major north-northwest transverse fault disrupting the East Rift Zone, and (2) in the region south and southeast of the structural break, flowing towards the sea and discharging as a series of hot springs and seeps along a portion of the island's southeastern coast. Mixed groundwater is located within the rift zone near Kapoho crater. This water type lies hydrologically downgradient from the region of upwelling geothermal fluids. The depth to groundwater at the project site is over 600 ft (180 m) below ground surface.

Site Water Quality

A study by TPC (Iovenitti, 1986) has found that the groundwater in the project site area is of the geothermal type. This results from the upwelling of fluids from the underlying geothermal reservoir. The waters are characterized by temperatures exceeding 100°F (38°C), TDS greater than 2,000 ppm, and chloride to magnesium ratios greater than 15. There is no groundwater within the lower East Rift Zone that can be defined as fresh water.

5.2 ENVIRONMENTAL IMPACTS OF THE PROPOSED ACTION

Construction Impacts

The following describes construction impacts on hydrology and water quality.

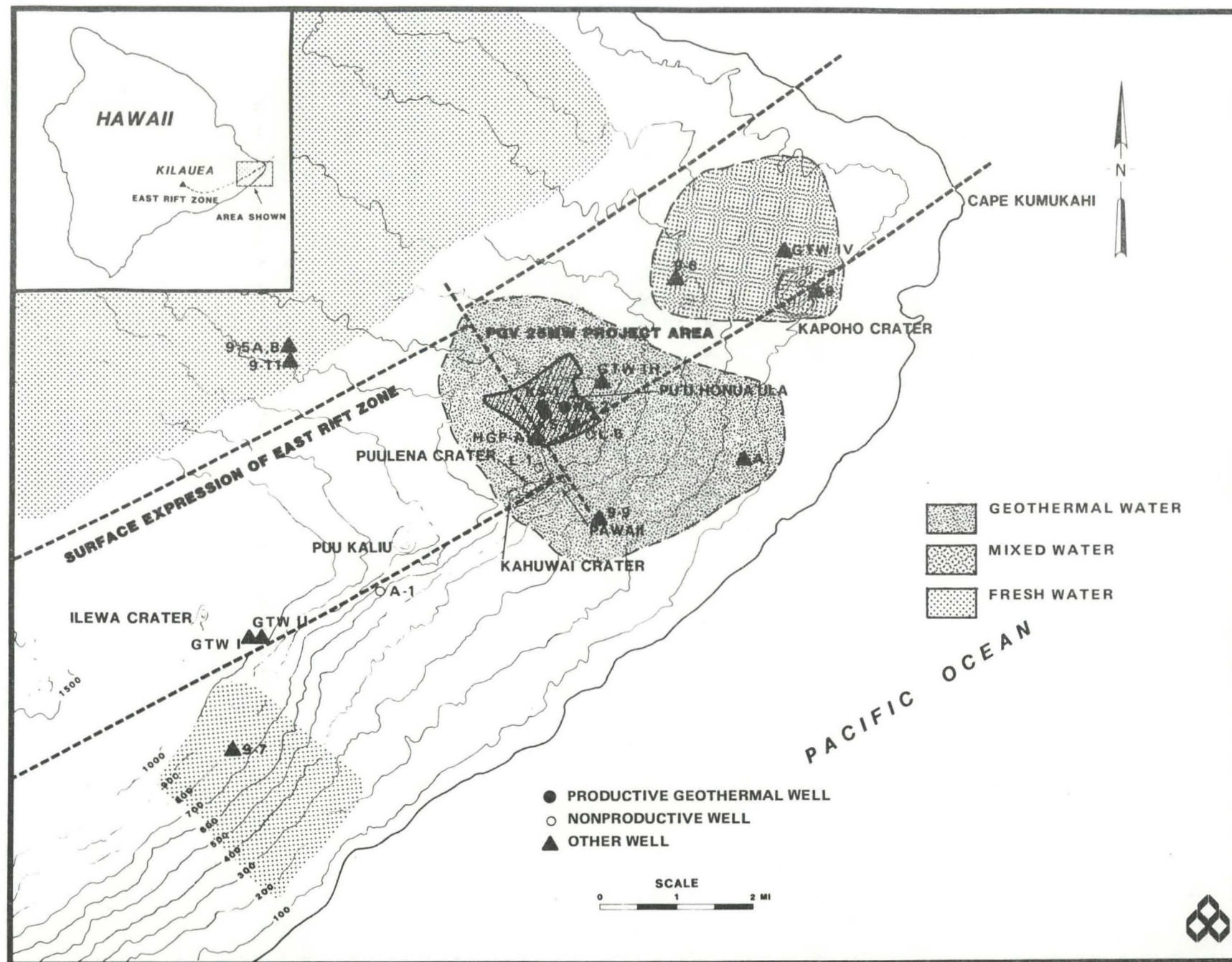


Figure 5-2 WATER TYPES IN THE LOWER EAST RIFT ZONE

Hydrology. Although there are no surface water drainages at the site, clearing and construction activities may create minor surface water drainage. These are not expected to affect the occurrence of groundwater.

Water Quality. During routine clearing and construction, minor spills of oil, gasoline, and other materials may occur. Procedures will be implemented to minimize such accidental spills, and mitigation measures will be established.

Under normal drilling operations, drilling fluids (a nontoxic mixture of clays of low mobility) will be discharged to unlined sumps and will percolate into the groundwater. Also, some loss of drilling fluid in the subsurface is expected. Since the groundwater at the site is of poor quality and not potable due to interaction with geothermal fluids, mixing of nontoxic drilling fluids with the groundwater will not impair groundwater quality.

During drilling into the deep geothermal reservoir (below 4,000 feet), the geothermal fluids encountered could migrate from the wellbore into the more shallow (less than 2,500 feet) geothermal groundwater that is not as saline and is cooler. This is unlikely, however, because the boring will be sealed with casing and grouted before drilling into the geothermal reservoir. Casing design requirements, casing materials, and cementing operations and procedures are established for geothermal wells and will be used on this project (Nicholson, 1984 a, b, c). Stringent drilling regulations will be enforced. However, should the deeper geothermal fluids reach the shallower water, the resulting impact would be minimal because it is a geothermal-type groundwater and is nonpotable.

During well testing, geothermal brines are planned to be discharged to a rock muffler at the test site. The rock mufflers will drain to unlined sumps, and the brine will percolate into the near-surface, nonpotable groundwater. The small volume of geothermal brine relative to the very large volume of existing nonpotable groundwater will result in minimal impact.

Operation Impacts

The following describes operation impacts on hydrology and water quality.

Hydrology. The power plant, production well, and injection well operation will not impact surface or groundwater hydrology.

Water Quality. The power plant and production well operations will have minimal impact on site groundwater. Operation of the geothermal wellfield will include the injection of fluids consisting of brine, condensed steam, cooling tower blowdown, and noncondensable gases. The constituents of the fluids are summarized in Section 2, Tables 2-1 and 2-2. Most liquids will be injected back into the geothermal reservoir at or below the 4,000-foot level and are not expected to have an impact on groundwater. The small volume of cooler water being injected is expected to be reheated quickly by the large geothermal reservoir. Noncondensable gas and entrained liquid injection is planned for the 1,500- to 2,000-foot depth interval beneath the site, which is above the reservoir seal. At this level, the groundwater has a moderate temperature (150-250°F) and is also nonpotable due to the upward leakage of the deeper geothermal fluids. The volume of noncondensable gas is expected to be easily soluble in this zone, which also contains some H₂S naturally leaking from the reservoir. Alternatively, the gases may be injected into the deeper geothermal reservoir, which is also not expected to impact the groundwater quality.

The wells will be cased and cemented. The same stringent regulations regarding geothermal well drilling will apply to injection well construction and operation. Any permanent brine holding ponds will be lined.

Faulting or subsurface lava movement could cause a rupture in the subsurface wellbore. However, due to the vertical nature of the faults in the project area, rupture of a wellbore is unlikely. If a casing rupture does occur, a temporary uncontrolled discharge of geothermal fluid will take place, and the fluid would mix with the groundwater. In this case, the discharge will continue until remedial measures are taken to secure or control the

leakage at the rupture point. No long-term adverse impacts from such an incident have been identified because the groundwater is nonpotable.

5.3 PROPOSED MITIGATION MEASURES

Construction Impacts

Hydrology. Clearing and construction activities will be limited and are not expected to affect the groundwater hydrology.

Water Quality. There are no identified impacts on groundwater quality during drilling since the groundwater is nonpotable. Nevertheless, the geothermal wells will be drilled according to stringent federal and state regulations designed to prevent discharge of reservoir fluid. During drilling operations, the wells will be cased and grouted at multiple depths to prevent reservoir fluid from escaping into the groundwater. Geothermal fluids tapped at lower depths will be prevented from migrating upward in the boring by carefully controlling the weight of the drilling fluid.

Precautions will be taken during storage and handling of petroleum and chemicals to avoid accidental spills (see Section 9). If an accidental spill occurs, it will be contained and cleaned up immediately.

Operation Impacts

The following describes mitigation of operation impacts on hydrology and water quality.

Hydrology. There are no anticipated adverse impacts on hydrology.

Water Quality. During operation of the geothermal wells, accepted procedures will be followed by all maintenance, operating, testing, and management personnel. Strict adherence to geothermal development regulations, State of Hawaii Department of Health regulations, and permit conditions for design and operation of production and injection wells will be maintained.

Geothermal brines and noncondensable gases will be injected back into the geothermal groundwater at depths with similar water quality characteristics. Thus, injection at the site is not expected to impact groundwater quality. In addition, strict underground injection control regulations and guidelines will be followed.

Hydrologic monitoring will be conducted in the injection area before, during, and after operation of the facility in accordance with federal and state department of health standards and permit requirements. A monitoring system will be implemented to detect any changes in the shallow and intermediate subsurface zones. Initially, baseline conditions (those that exist prior to injection) will be established to determine hydrologic changes that may occur during injection. These conditions include:

- o Chemical characteristics of the groundwater
- o Geology and hydrology of the area
- o Mechanics and characteristics of the geothermal system

Chemical changes in the groundwater will occur in a spatial and temporal matrix. The necessary chemical, spatial, and temporal sensitivity of detection in the matrix will be specified based on the environmental sensitivity to particular constituents; natural variations in water characteristics; hydrologic factors; and water use and well distribution density in the area.

Analysis of these parameters will aid in determining sampling frequency, distribution and density of sample points, significant chemical and physical parameters, and sampling and analysis methods to be utilized.

Implementing the monitoring plan will involve data collection at specified frequency and locations, and synthesis, interpretation, and display of the data. Past data will be reviewed and correlated with new data. As the plan is carried out, the actual monitoring needs of the area will become clearer, and the plan can be modified as appropriate for enhanced monitoring.

Power Plant and Well Decommissioning Impacts

The following describes mitigation of power plant and well decommissioning impacts on hydrology and water quality.

Hydrology. No impacts on site hydrology from power plant and well decommissioning are expected. Therefore, no mitigation measures will be necessary.

Water Quality. No impacts are expected on site water quality from power plant and well decommissioning. Therefore, no mitigation measures will be necessary. Furthermore, the geothermal wells will be abandoned and plugged in accordance with regulatory requirements. Project water quality monitoring will be continued for 2 years after decommissioning (two rain seasons maximum), and the records will be placed in the public domain.

Section 6
Air Quality

Section 6

AIR QUALITY

This section describes the regional climate, site meteorology, and baseline air quality of the PGV project. Air emissions have been reduced from the usual significant environmental impact to a level of insignificance, due to the total injection process proposed for this project. The total injection process takes the noncondensable gases associated with the project and injects them into the ground. Thus, air emission impacts are limited to incidents of temporary well testing and steam stacking, or the unlikely event of a well blowout or rupture disk event.

6.1 ENVIRONMENTAL SETTING

Regional Climate

The Hawaiian Islands lie within the trade winds belt. The trade winds (trades) are an outflow of air from the central North Pacific high pressure region located generally to the north and east of the Hawaiian Island chain. On the island of Hawaii, the trades flow is generally from the northeast. The Pacific High moves north and south with the sun, so that in summer, it is at its northernmost position and brings the heart of the trades directly across the island. However, the local ruggedness of the terrain results in markedly different wind flow patterns and local climates on the island.

In summer (May through September), the trades are prevalent 80 to 95 percent of the time. From October through April, the trades are more northerly, and their frequency is generally 50 to 80 percent of the time in average monthly values (Ruffner and Bair, 1978). The trades exert a dominant influence on the general climate of the islands. Clear skies are rare, as clouds frequently form on the upslope sides of the mountains. For example, at Hilo, the sky is clear from sunrise to sunset an average of 31 days per year, partly cloudy 125 days per year, and cloudy 209 days per year. Showers are frequent, varying from sudden sprinkles to heavy downpours; however, thunder

and lightning occur rarely. Because the trades are generally constant movements of mild marine air, the range of diurnal temperature change is narrow. Because of the latitude (about 21 degrees north), the days are approximately the same length throughout the year.

In Hawaii, major storms occur most frequently between October and March, bringing heavy rains that are sometimes accompanied by high winds. The storms may be generated by the passage of cold fronts moving to the east or southeast, or by low pressure regions of warm, moist air that produce tremendous clouds and torrential rains.

In addition to these large-scale air flows, other smaller, local air movements occur, which range in scale from a few to many square kilometers, depending on the areal extent of the affected land. These movements are most commonly found on lands to the south and west of the mountains, in their aerodynamic shadow. The topography is important in determining these local wind occurrences. Some of these air flows occur diurnally and are either upslope/downslope (valley) flows or onshore/offshore (sea breeze) flows. Both flows are driven by radiative thermal gradients.

The site of the PGV project is about 21 mi (34 km) from Hilo, Hawaii. Long-term climatic data are available from the National Weather Service (NWS) station at General Lyman Field (Hilo Airport). The NWS data are fairly representative of the PGV site. Table 6-1 shows the climatic normals, means, and extremes for the Hilo Airport NWS data.

Temperature. The difference between the normal monthly mean temperature of 75.9°F (24.4°C) for the warmest month, August, and 71.0°F (21.7°C) for the coolest month, February, illustrates the steadiness of the climate. The difference is a remarkably small annual mean variation of 4.9°F (2.7°C). The record high temperature of 94°F (34.4°C) was recorded in May 1966, and the record low temperature of 53°F (11.7°C) was recorded in February 1962.

Table 6-1
CLIMATE NORMALS, MEANS, AND EXTREMES
(Source: Ruffner and Bair, 1978)

Month	Normal Degree days Base 65 °F		Precipitation in inches										Relative humidity pct.				Wind				Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset	Mean number of days												Average station pressure mb.	
	Heating	Cooling	Water equivalent						Snow, ice pellets				Hour 02	Hour 08	Hour 14	Hour 20	Mean speed m.p.h.	Prevailing direction	Fastest mile				Sunrise to sunset			Precipitation .01 inch or more	Snow, ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ¼ mile or less	Temperatures °F				Elev. 36 feet m.s.l.		
			Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Maximum monthly	Year	Maximum in 24 hrs.							Year	Speed m.p.h.			Direction	Year	Clear					Partly cloudy	Cloudy	90° and above	32° and below		32° and below	0° and below
(a)				33		33		33		33		33		26	26	26	26	26	14	9	9		25	29	29	29	33	33	30	30	30	30	30	30	3	
J	0	192	9.07	29.11	1949	0.36	1953	9.94	1949	0.0		0.0	84	80	67	83	7.5	SW	30	SE	1968	44	6.7	5	12	14	18	0	1	0	0	0	0	1014.1		
F	0	176	12.90	43.66	1969	1.70	1963	15.70	1969	0.0		0.0	85	80	67	82	7.9	SW	26	SE	1975	42	6.9	4	10	14	18	0	1	0	0	0	0	1016.7		
M	0	185	13.69	31.91	1948	0.88	1972	9.18	1953	0.0		0.0	87	81	67	83	7.7	SW	29	SE	1972	38	7.7	2	10	19	24	0	2	0	*	0	0	0	1017.6	
A	0	216	12.88	31.94	1963	2.93	1962	11.07	1971	0.0		0.0	88	82	69	84	7.5	WSW	23	SE	1968	33	8.2	1	8	21	25	0	1	0	0	0	0	1017.2		
M	0	264	10.07	25.01	1964	1.18	1945	10.26	1965	0.0		0.0	88	80	68	83	7.3	WSW	22	E	1969	34	8.0	1	10	20	25	0	1	0	*	0	0	0	1017.0	
J	0	288	6.61	15.50	1943	2.68	1949	2.23	1963	0.0		0.0	87	78	65	82	7.2	WSW	21	E	1968	41	7.6	2	10	18	24	0	*	0	*	0	0	0	1016.8	
J	0	319	9.54	14.89	1958	3.83	1975	5.42	1951	0.0		0.0	88	81	67	82	6.9	WSW	26	SE	1974	41	7.7	1	12	18	27	0	*	0	0	0	0	0	1016.5	
A	0	338	10.88	26.42	1957	2.66	1971	9.65	1970	0.0		0.0	88	81	68	83	6.9	WSW	25	NW	1972	40	7.6	1	11	19	27	0	*	0	*	0	0	0	1015.8	
S	0	318	7.44	13.63	1947	1.59	1974	6.02	1960	0.0		0.0	87	79	67	83	6.8	WSW	20	E	1972	41	7.1	3	12	15	23	0	*	0	*	0	0	0	1015.3	
O	0	310	10.96	26.10	1951	2.40	1962	8.88	1951	0.0		0.0	87	80	68	85	6.7	SW	24	SE	1972	39	7.2	3	12	16	24	0	1	0	*	0	0	0	1015.6	
N	0	255	13.77	27.03	1959	3.74	1943	15.59	1959	0.0		0.0	87	82	70	86	6.8	WSW	22	SE	1975	33	7.4	3	10	17	24	0	1	0	0	0	0	0	1014.7	
D	0	205	15.76	50.82	1954	0.77	1963	10.50	1946	0.0		0.0	86	82	70	85	7.3	SW	30	NW	1973	35	7.1	4	11	16	22	0	1	0	*	0	0	0	1015.7	
YR	0	3066	133.57	50.82	DEC 1954	0.76	JAN 1943	15.70	FEB 1969	0.0		0.0	87	81	68	83	7.2	WSW	30	NW	DEC 1973	39	7.4	30	128	207	282	0	9	0	1	0	0	0	1016.1	

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Lowest temperature 51 in May 1910; maximum monthly precipitation 66.96 in March 1922; minimum monthly precipitation 0.14 in January 1953; maximum precipitation in 24 hours 19.20 in March 1922; highest wind (fastest observed 1-minute speed) for period 1954-1966 was 46 from 70° in February 1963.

Precipitation. Precipitation is a function of elevation above mean sea level (MSL). For example, for the 1931 to 1960 base period, the normal annual rainfall at Hilo Airport, which is 27 ft (8.2 m) above MSL, was 136.6 in. (3,470 mm), while the mean annual rainfall can exceed 200 in. (5,080 mm) in the mountains. At Pahoa, 5 mi (8 km) from the PGV site at an elevation of 670 ft (204 m) above MSL, the normal annual rainfall was 143.8 in. (3,653 mm). Therefore, the rainfall values at the PGV site could be slightly larger than those reported at Hilo Airport.

For the same base period at Hilo Airport, nearly 70 percent of the rain occurred during the cooler months (October through April), the so-called Hoo-Ilo season, when the sun is in the south, temperatures are slightly cooler, and the trades are less steady and more frequently interrupted by stormy periods. The maximum monthly rainfall was 50.22 in. (1,276 mm) in December 1954. The minimum monthly rainfall was 0.36 in. (9.1 mm) in January 1953. The maximum 24-hour rainfall was 15.6 in. (396 mm) in November 1959. No occurrences of snow or sleet have been recorded at lower elevations.

Winds. Winds at Hilo average 7.2 mph (3.2 m/s), with a mean maximum month (February) average of 8.0 mph (3.6 m/s) and a mean minimum months (September through November) average of 6.8 mph (3.0 m/s). The annual resultant direction of the winds is west/southwest. Monthly directions are from either the west/southwest or southwest. Therefore, the wind direction at Hilo is about 180 degrees counter to the expected trades flow. This is attributed to the special situation at Mauna Loa where the onshore flow is lifted to provide an upslope wind by day while a drainage flow with a counter downslope wind develops at night and in the early morning hours. This latter flow predominates (Ramage, 1978). Clearly, local terrain features tend to define the wind flows and their influence predominates over the synoptic flow of the trade winds. The wind flows specific to the project site are discussed in the next subsection.

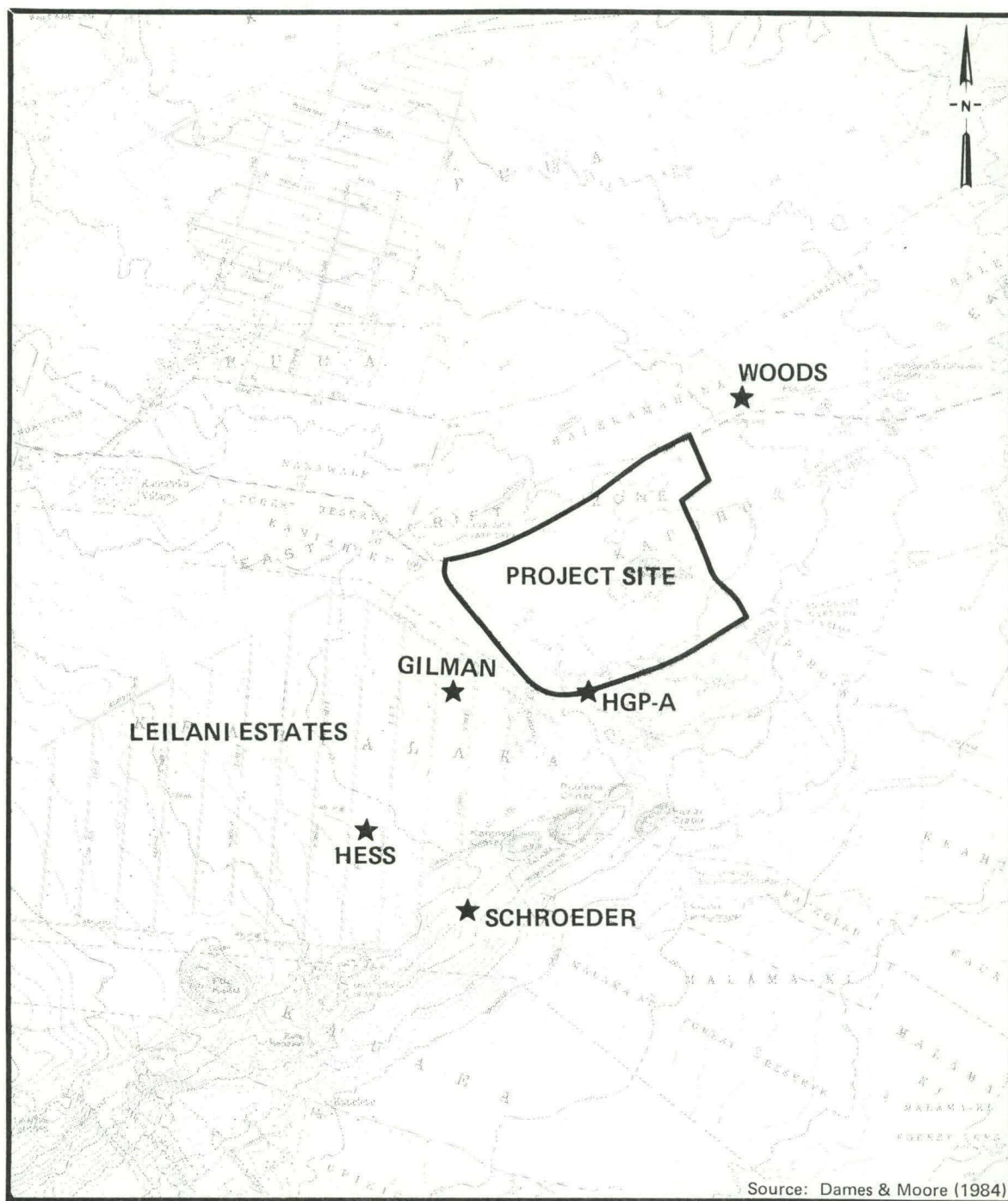
The ability of air in the surface layers (up to a few thousand vertical meters) to disperse contaminants varies diurnally and seasonally. One measure of this dispersal capability is the mean maximum mixing depth (MMD). MMDs can

be estimated with the method of Holzworth (1964) using the daily radiosonde observations and normal maximum surface temperatures. Daily morning and afternoon mixing heights reported at Hilo (Dames & Moore, 1984) indicate that afternoon mixing heights are higher (average 5,420 ft [1,652 m]) than mornings (average 4,144 ft [1,263 m]) except for February, and that summer heights are higher than those in winter. A higher mixing height allows greater dispersion of air pollutants and, consequently, favors better air quality. Therefore, lower pollutant concentrations would be expected in summer than in winter, and during daytime than at night.

Site Meteorology

TPC has conducted meteorology and air quality monitoring studies in the Puna region since 1981. Observations made at the Woods Site include wind speed and direction, standard deviation of wind direction fluctuation (sigma theta), temperature, relative humidity, precipitation, and insolation. The Woods Station is located about 1.1 mi (1.7 km) north of HGP-A, as shown in Figure 6-1. Annual wind roses for the period of May 1981 to May 1982 are presented in Figure 6-2, 6-3 and 6-4 for all hours, daytime and nighttime hours, respectively (W. Burkhard, private communication, 1986). It appears from these wind roses that the wind flow is from the north to northeast during the daytime and from the west during the nighttime. The nighttime westerly winds derive from downslope flows. The north-to-northeast daytime winds derive from the trades. The average annual wind speed for all hours is 7.4 mph (3.3 m/s) with daytime and nighttime annual average wind speeds of 8.5 mph (3.8 m/s) and 6.3 mph (2.8 m/s), respectively. The Woods Site meteorological data, which represent the most complete information for the site, were also summarized for 1 year, October 1982 to September 1983 (Dames & Moore, 1984). This 1982-1983 data set was used for the air quality impact calculations.

An annual wind rose summary of these data is shown in Figure 6-5. As expected, this wind rose is very similar to that for the period of May 1981 to May 1982, shown in Figure 6-2. The average annual wind speed is 6.5 mph (2.9 m/s), which is similar to the value reported for the period of May 1981



★ — Stations

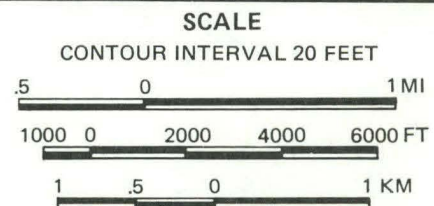


Figure 6-1 AIR QUALITY MONITORING STATIONS

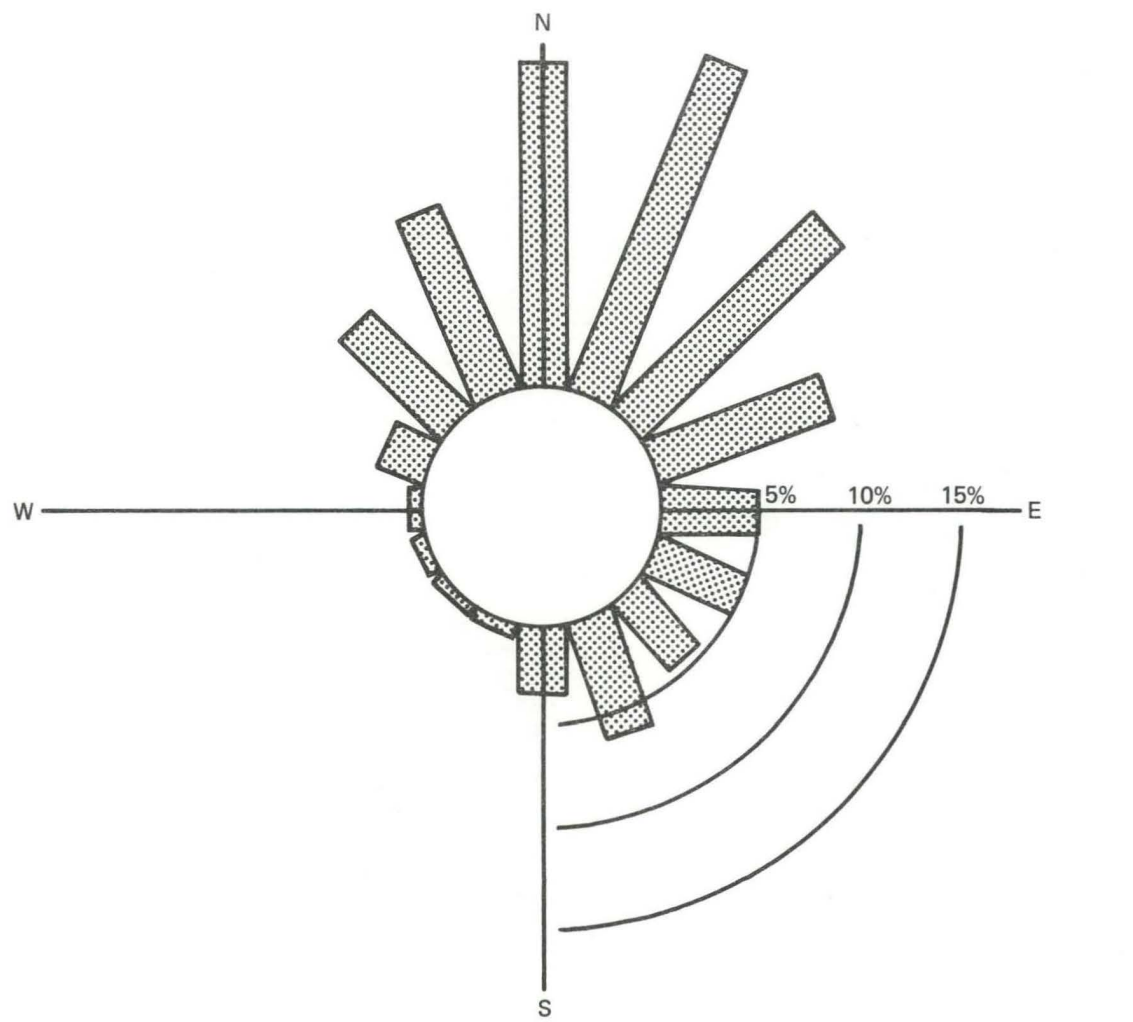


Figure 6-3 ANNUAL DAYTIME WIND ROSE FOR THE WOODS SITE (SITE 36)
MAY 1981 TO MAY 1982

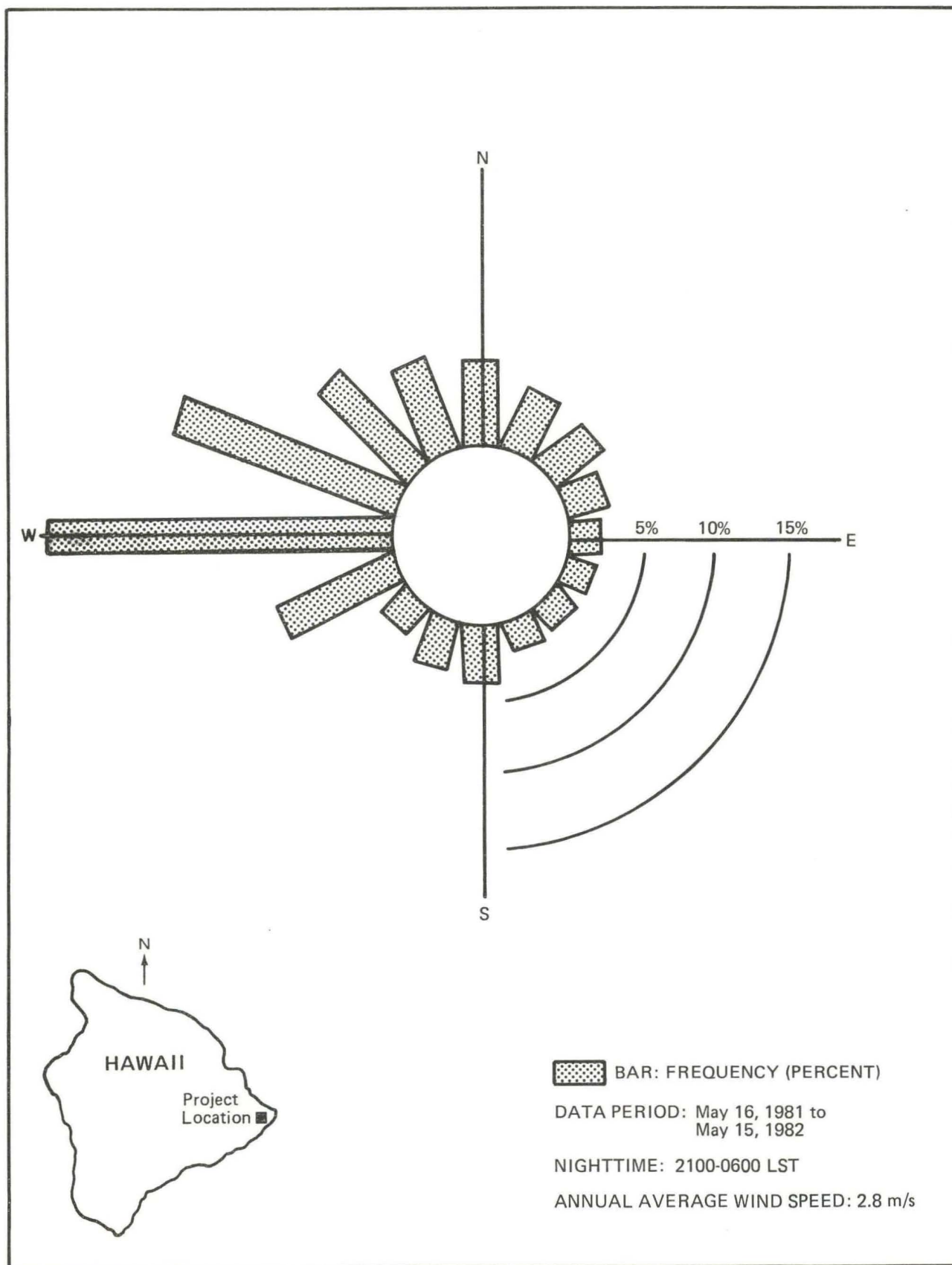


Figure 6-4 ANNUAL NIGHTTIME WIND ROSE FOR THE WOODS SITE (SITE 36)
MAY 1981 TO MAY 1982

to May 1982. The strongest winds, 8.3 mph (3.7 m/s), blow from the southwest. Daily mid-afternoon winds are strongest, 9 mph (4 m/s), and evening hours winds are the lightest, 4.5 mph (2 m/s).

Measurements of wind direction variation yield estimates of the atmosphere's dilution capability or stability. Stability, which is a measure of turbulence, is used to estimate diffusion of releases into the air. Stability varies from category A (very unstable), B (unstable), and C (slightly unstable), to D (neutral), E (slightly stable), and F (stable). Atmospheric mixing and dispersion are greatest during unstable conditions, which occur only during daylight hours. Table 6-2 shows the typical annual frequency of each stability category at the site.

Table 6-2

FREQUENCY OF ATMOSPHERIC STABILITY CATEGORIES AT THE WOODS SITE

<u>Category</u>	<u>Percent of Time</u>
A (very unstable)	2.5
B plus C (unstable to slightly unstable)	25
D (neutral)	50
E (slightly stable)	20
F (stable)	2.5

Baseline Ambient Air Quality

NEA, Inc. reported ambient H_2S for the Hawaii Department of Planning and Economic Development (Dames & Moore, 1984). Monitoring stations, shown in Figure 6-1, include:

- o Schroeder Site, located about 1.2 mi (2 km) south southwest of the HGP-A site. H_2S data collection began in March 1981.
- o Hess Site, located about 1.2 mi (2 km) southwest of the HGP-A well site. H_2S data collection began in July 1982.
- o Gilman Site, located about 0.6 mi (1 km) west of the HGP-A well site. Monitoring began in July 1982.

- o Woods Site, located about 1.1 mi (1.7 km) north of the HGP-A well site. Monitoring began in 1981, and comprehensive data collection began in April 1982.

Data collected and reported through 1983 for the first three sites and through August 1986 for the Woods Site are shown in Table 6-3. These data indicate that H_2S ambient levels are below 0.010 ppmv^(a) ($14 \mu g/m^3$) about 98 percent of the time. H_2S levels exceeded 0.020 ppmv ($28 \mu g/m^3$) less than 1 percent of the time. The maximum H_2S level reported was 0.048 ppmv ($67 \mu g/m^3$) at the Schroeder Site. This site is located downwind of the HGP-A well site. These H_2S ambient levels can be compared with the standard of 0.1 ppmv ($140 \mu g/m^3$) proposed by the State of Hawaii Air Advisory Committee.

Particulate matter (PM) has also been monitored using hi-vol samplers at two locations in Puna. The first location is the Bishop Estates Leasehold, about 2.5 mi (4 km) southwest of the HGP-A well; the second is the visitor center of Hawaii Volcanoes National Park (a mandatory PSD Class I area), about 12.5 mi (20 km) northwest of the well site. Data from the Bishop Estates Leasehold showed that between December 1982 and March 1983, the 14 biweekly samples at each site averaged a 24-hour PM level of $20 \mu g/m^3$ at the leasehold. The highest value at the visitor center was $39 \mu g/m^3$. These PM values can be compared to the National Ambient Air Quality Standards (NAAQS): $260 \mu g/m^3$ (primary standard)^(b) and $150 \mu g/m^3$ (secondary standard)^(c).

(a) ppm refers to parts per million by weight; ppmv refers to parts per million by volume.

(b) Primary standards are the levels of air quality necessary, with an adequate margin of safety, to protect the public health.

(c) Secondary standards are levels of air quality necessary to protect the public from any known or anticipated adverse effects from a contaminant.

Table 6-3

ONE-HOUR AVERAGE HYDROGEN SULFIDE CONCENTRATIONS
IN THE HGP-A WELL AREA (1981-1983)

Site	H ₂ S Concentration Range (ppmv)	Number of Observations		
		1981	1982	1983
Schroeder ^(a)				
	0-0.01	4,464	6,476	NA ^(b)
	0.011-0.02	233	225	0
	0.021-0.03	25	12	0
	0.031-0.04	2	5	0
	0.041+	2	2	0
Total number of observations		4,726	6,720	NA
Maximum H ₂ S concentration (ppmv)		0.045	0.048	0.007
Average H ₂ S concentration (ppmv)		0.0042	0.0044	0.0014
Gilman ^(c)				
	0-0.01	(d)	3,924	NA
	0.011-0.02	--	4	0
	0.021+	--	0	0
Total number of observations		--	3,928	NA
Maximum H ₂ S concentration (ppmv)		--	0.016	0.008
Average H ₂ S concentration (ppmv)		--	0.0030	0.0012
Hess ^(c)				
	0-0.01	--	3,635	NA
	0.011-0.02	--	90	0
	0.021+	--	0	0
Total number of observations		--	3,725	NA
Maximum H ₂ S concentration (ppmv)		--	0.014	0.004
Average H ₂ S concentration (ppmv)		--	0.0035	0.001

Table 6-3 (Cont'd)

Site	H ₂ S Concentration	Number of Observations					
	Range (ppmv)	1981	1982	1983	1984	1985	1986 ^(f)
Woods ^(e)	0-0.01	NA	5,633	3,512	NA	NA	NA
	0.011-0.02	NA	0	0	NA	0	NA
	0.021+	0	0	0	0	0	0
Total number of observations		NA	5,633	3,512	NA	NA	NA
Maximum H ₂ S concentration (ppmv)		0.013	0.007	0.004	0.013	0.009	0.015
Average H ₂ S concentration (ppmv)		0.0026	0.0019	0.001	0.0016	0.0018	0.0024

(a) Data from May 1981 through September 1983 (missing June 1982 data).

(b) Data not available.

(c) Data from July 1982 through September 1983.

(d) Station not operating during this time.

(e) TPC has been monitoring H₂S at the Woods Site continuously since 1981. Comprehensive data were obtained from April 1982 through August 1986 (missing April 1983 data).

(f) Through August 1986 only.

NA = Data not available

Sources: Dames & Moore, 1984; W. Burkhard, private communication, 1986.

6.2 ENVIRONMENTAL IMPACTS OF THE PROPOSED ACTION

In this subsection, the impacts of the various phases of the proposed project are evaluated. The three phases that are considered include clearing and construction activities, operation of the geothermal power plant, and decommissioning of the facility.

Dispersion Modeling

Air quality impacts were assessed by dispersion modeling techniques.

Dames & Moore (1984) used the EPA MPTER and the EPA COMPLEX I models. MPTER is used for multiple sources with relatively flat terrain and land elevations no higher than the shortest stack modeled. The model calculates highest ground-level concentrations (GLCs) at receptors for averaging times ranging from 1 to 24 hours and for the entire period of meteorological data. The COMPLEX I model, which is used for complex (hilly) terrain, is similar to the EPA Valley model, but is more sophisticated. It uses hourly meteorological data for a year as input and calculates the highest GLC for 1 to 24 hours. It also calculates an annual average GLC.

For the Dames & Moore modeling, TPC meteorological data from the Woods monitoring station, summarized in Figure 6-5, were used. The data from February 1982 through January 1983 were 3-hour averages. From February 1983 through September 1983, the data were reported as 1-hour averages for every hour of the day. To obtain 1 year of the best data, the 3-hour data of October 1982 through January 1983 were combined with the 1-hour data of February 1983 through September 1983 to give 1 year of data for October 1982 through September 1983. For the 3-hour data, each hour was assumed to be representative of the 3 hours. Dames & Moore felt that this adjustment might introduce minor biases in the results, but that it was more important to consider an entire year of data. Both MPTER and COMPLEX I require 24 observations per day to correctly model for short-term (1- to 24-hour) atmospheric diffusion. A mixing height of 900 ft (300 m) was adopted as a conservative limit, but this did not affect GLCs, since they occurred during stable conditions when mixing heights did not affect plume dispersion.

Bechtel National, Inc. used the EPA Valley model to evaluate maximum 1-hour average impacts of the cooling tower plume pollutants on the surrounding complex terrain during operation of the facility. These impacts were calculated for H_2S and TSP concentrations. These maximum values were calculated using worst case meteorological conditions.

The results of the dispersion modeling calculations are presented in the following subsections.

Impacts of Clearing and Construction Activities on Air Quality

Clearing and construction activities include drilling and testing of the geothermal wells and site clearing and construction of the power plant and wellpads.

Well Drilling and Testing. The atmospheric impact of wellfield construction will derive principally from the rotary drilling rig emissions. Only one rig will be on the site at a time. Drilling time for the six production wells and two injection wells is estimated to be 8 months for Phase I (four wells) and 8 months for Phase II (four wells). The estimated emissions are listed in Table 6-4.

During well drilling, fluid is forced down through the center of the drill pipe and comes back up around the pipe carrying the cuttings produced by the drilling. The fluid can be either mud or air forced down by compressors.

If air drilling is used, significant H_2S and TSP emissions may result. Table 6-5 lists the assumptions made to estimate an H_2S emission rate of 4.7 lb/hr (0.6 g/s) for air drilling. The proposed technique, however, is mud drilling, which would lead to negligible emissions of H_2S and TSP. Air drilling would be used only in the plant operation phase of the project as a remedial technique. Therefore, air drilling would be used only 5 percent of the total drilling time. The GLCs for H_2S that are presented in Table 6-5 for well drilling represent H_2S concentrations resulting from air drilling. The concentrations that would result with the proposed mud drilling technique would be negligible.

Table 6-4

DRILLING RIG EMISSIONS DURING WELLFIELD CONSTRUCTION^(a)

<u>Item</u>	<u>Emission</u>		
	<u>Grams/hour</u> ^(b)	<u>Kilograms/day</u> ^(c)	<u>Metric tons/year</u> ^(d)
CO	188	4.50	1.37
HC	71	1.71	0.52
NO _x	1,030	24.72	7.51
SO ₂	65	1.56	0.47
TSP	63	1.50	0.46

(a) Based on EPA document AP-42, Sppl. 14, May 1983, pp. 3.2.7-2,3. These values pertain to oil well drilling rather than geothermal well drilling. However, rigs are generally similar for oil and geothermal well drilling, and these emissions are good approximations of the emissions for the proposed project.

(b) Based on one drilling rig.

(c) Based on a 24-hour day.

(d) Based on a 10-month (304-day) period for Phase I (five wells).

Table 6-5

WELL AIR DRILLING AND TESTING: ESTIMATED AIR POLLUTANT EMISSIONS
AND MAXIMUM AMBIENT CONCENTRATIONS DUE TO WELL EMISSIONS

Item	H ₂ S				TSP(a)		
	Estimated Emissions Per Well		Incremental Ground-Level Concentrations		Emissions		Highest 24-hr average Incremental Ground-Level Concentration
			ppmv (µg/m ³)				
			Highest 1-hour Average	Second Highest 1-hour Average			
	lb/hr	g/s			lb/hr	g/s	(µg/m ³)
Drilling (b)	4.7	0.60	0.017 (24)	0.006 (8)	34.4	4.3	45
Testing (c)	9.8	1.24	0.036 (50)	0.012 (17)	43.1	5.4	55
Proposed AAQS(d)	--	--	0.10 (140)	--	--	--	100
Proposed allow- able increment(e)	--	--	0.025 (35)	--	--	--	--

- (a) Total suspended particulate (TSP) impacts were modeled assuming gaseous dispersion. However, due to their droplet nature, significant dropout near the source will occur; hence, the emissions and ground-level concentrations shown represent an upper bound. The emission rates of particulate matter (Y) were estimated from the steam flow rate (X) according to the following equation: $Y = 0.00029 X - 0.42$ where X and Y are in lb/hr (Dames & Moore, 1984)
- (b) Impacts are evaluated on a per well basis assuming air drilling. The proposed technique is mud drilling which should lead to negligible H₂S and TSP emissions. Air drilling would be used only in the plant operation phase of the project as a remedial technique (i.e., 5% of the time). The H₂S and TSP concentrations reported in this table for drilling are therefore overestimates. The assumptions for well air drilling were as follows: fluid flow per well of 150,000 lb/hr (19,000 g/s), maximum H₂S content of 1,300 ppm, drill pipe flow restriction of 20%, removal of 40% of H₂S by water injection, removal of an additional 95% of H₂S by chemical injection of water and NaOH. No control was assumed for TSP.
- (c) Impacts are evaluated on a per well basis.
- (d) Proposed H₂S ambient air quality standard (AAQS) is 0.10 ppmv (140 µg/m³) per Hawaiian Air Advisory Committee recommendation, Chapter 59, January 18, 1983. AAQS for TSP is per Department of Health, Chapter 59, Par. 11-59-4-(e)-(2), November 29, 1982.
- (e) Proposed H₂S increment allowable above background, equivalent to 0.025 ppmv (35 µg/m³), per Hawaiian Air Advisory Committee Chapter 60 recommendation, 1983.

Source: After Dames & Moore (1984)

H₂S emissions from well testing were based on one well and 150,000 lb/hr (19,000 g/s) steam flow. Uncontrolled H₂S emissions would be about 195 lb/hr (25 g/s), and controlled H₂S emissions, assuming 95 percent control (Geothermal Technical Services, 1986), would be 9.8 lb/hr (1.2 g/s).

TSP emissions from well testing were estimated based on a well capacity of 150,000 lb/hr (19,000 g/s) of steam to be 43 lb/hr (5.4 g/s).

Both the MPTER and COMPLEX I model were used, but it was found that in all cases the region of maximum GLCs occurred at higher elevations with the COMPLEX I model.

The results of the H₂S and TSP impacts calculated by the COMPLEX I model are presented in Table 6-5. The results of the modeling for well drilling showed a maximum 1-hour H₂S GLC of 0.017 ppmv (24 µg/m³) and a maximum 24-hour TSP GLC of 45 µg/m³. Well testing results showed a maximum 1-hour H₂S GLC of 0.036 ppmv (50 µg/m³) and a maximum 24-hour TSP GLC of 55 µg/m³. The H₂S GLC for well testing is above the proposed state increment. However, note that this GLC value was obtained with worst-case assumptions and that the second-highest GLC is well below the proposed state increment. Moreover, well testing will be temporary which reduces the likelihood of occurrence of the highest H₂S GLC.

Since H₂S background concentrations are less than 0.048 ppmv (67 µg/m³), the ambient H₂S concentrations would be less than 0.065 ppm (91 µg/m³) for well air drilling and less than 0.084 ppm (117 µg/m³) for well testing (see Table 6-3). Therefore, the proposed Chapter 59 H₂S ambient air quality standards (AAQS) of 0.10 ppmv (140 µg/m³) will be met. TSP maximum GLCs are below the state AAQS of 100 µg/m³, since the highest 24-hour average TSP increment is 55 µg/m³ for well testing and TSP background concentrations are about 20 to 40 µg/m³.

Impacts of the Construction of the Power Plant and Associated Facilities

Clearing and construction activities will impact air quality due to construction equipment emissions and the fugitive dust emissions from the

general ongoing surface activity. These activities and the associated air quality impacts will, however, be temporary. Table 6-6 presents equipment emissions from clearing and grubbing activities. The principal equipment items are listed, together with the estimated contaminant emissions. The schedule is based on an 8-hour day. The total time required for site development (including excavation and required backfill) is estimated to be 5 months.

Power plant construction will include foundations and structures, turbine-generators, electrical switchgear, and other requirements. The construction time is estimated to be 12 months and can begin approximately 1 month after the start of site preparation.

Fugitive dust emissions result from heavy construction activities, such as building and road construction, land clearing, blasting, ground excavation, and cut and fill operations. Fugitive dust emission levels vary depending on the specific work in progress and the prevailing weather. Based on work by Cowherd (1974) and EPA reports (AP-42, 1984, p. 11.2.4-1), a fugitive emission factor of 1.2 tons/acre of construction per month of activity was proposed. This emission factor relates to test data from a location with a semi-arid climate and a precipitation-evaporation (PE) index of 50. For the Puna area, with its higher rainfall, the PE index (based on Hilo Airport data) is 202. Applying the correction ($f = 1/(202/50)^2$) and allowing for 12 acres of disturbed area and 5 acres of temporary construction area, the corrected fugitive emissions for heavy construction amount to about 2,500 lb/month (1.135 metric tons/month).

Estimates of gaseous engine exhaust emissions from construction equipment used during power plant construction are shown in Table 6-7. These emissions should not lead to any air quality impacts exceeding the standards.

Cox (1981) reported mercury (Hg) concentrations in the soil ranging from 0.015 to 1.25 ppm. Assuming an upper limit of $100 \mu\text{g}/\text{m}^3$ for fugitive dust concentrations (i.e., the state AAQS), the corresponding mercury concentration would be less than $1.25 \times 10^{-4} \mu\text{g}/\text{m}^3$. This value is well below the ambient level goal of $0.01 \mu\text{g}/\text{m}^3$ given by Cleland and Kingsbury (1977).

Table 6-6

DIESEL EMISSIONS DURING CLEARING AND GRUBBING^(a)

Item	Emission (grams/hour)				Total		
	Dozer	Trucks ^(b)	Loader	Roller	Grams/hour	Kilograms/ ^(c) day	Metric tons/ ^(d) year
CO	335	1,830	251	84	2,500	20.00	2.20
HC	106	594	85	25	810	6.48	0.71
NO _x	2,290	10,380	1,090	474	14,230	113.87	12.53
SO ₂	158	618	83	31	890	7.12	0.78
TSP	75	348	78	23	520	4.19	0.46

(a) Based on EPA document AP-42, Sppl. 14, May 1983, pp. 3.2.7-2,3.

(b) Based on three trucks.

(c) Based on an 8-hour day.

(d) Based on a 5-month (110-day) period.

Table 6-7

DIESEL EMISSIONS DURING POWER PLANT CONSTRUCTION (a)

<u>Item</u>	<u>Emission (grams/hour)</u>				<u>Total</u>		
	<u>Dozer</u>	<u>Trucks^(b)</u>	<u>Loader</u>	<u>Roller</u>	<u>Grams/hour</u>	<u>Kilograms/^(c) day</u>	<u>Metric tons/^(d) year</u>
CO	251	3,050	335	677	4,310	34.5	8.97
HC	85	990	106	257	1,440	11.5	2.99
NO _x	1,090	17,300	2,290	3,708	24,390	195.1	50.73
SO ₂	83	1,030	158	233	1,500	12.0	3.13
PM	78	580	75	228	960	7.7	2.00

(a) Based on EPA document AP-42, Sppl. 14, May 1983, pp. 3.2.7-2,3.

(b) Five trucks, including concrete transit mix trucks, and water truck.

(c) Based on an 8-hour day.

(d) Based on a 5-day week, 52 weeks/year, or 260 days/year.

The region is quite rainy, with at least 75 percent of the days at Hilo with over 0.01 inch (0.25 mm) of rain, and the ground can still be damp and dust-free even on clear days. Therefore, the climatic conditions will favor the control of fugitive dust during construction activities.

Impacts of the Power Plant Operation on Air Quality

Pollutants will be emitted during the normal operation of the facility from the cooling tower during operation of the power plant and from the rock muffler during steam stacking (i.e., venting through the rock muffler). Pollutants will also be emitted in the unlikely event of a well blowout or an operator error resulting in abnormal steam pressure buildup in a pipeline and the subsequent release of steam through the rupture disk system. The air quality impacts of the pollutant emissions are analyzed below.

Noncondensable gas emissions from the power plant during normal operations will originate from the cooling tower and will include CO_2 and H_2S . No measurable quantities of boron, arsenic, mercury, or radon have been detected in recent source tests of the HGP-A well (Dames & Moore, 1984). TSP are also emitted. The analysis for the proposed project focused on the ambient concentrations of H_2S and TSP since these two pollutants are the object of existing or proposed regulations. The analysis considered emissions of these pollutants from the cooling tower, as well as from the rock muffler during steam stacking and in the unlikely case of a well blowout or a rupture disk event.

Dames & Moore (1984) reported results of modeling H_2S emissions during steam stacking. Their modeling results were adjusted by applying the rule of proportionality between emissions and GLCs to reflect the latest information on steam flow and H_2S content for the proposed project.

Modeling of H_2S and TSP emissions during normal operations was carried out by Bechtel National, Inc. for worst case conditions with the EPA Valley model. The impact of pollutant emissions resulting from a well blowout and a

rupture disk event was deduced from the modeling results of Dames & Moore (1984) by scaling emissions and GLCs.

There is no federal AAQS for H_2S . In 1983, the State of Hawaii Air Advisory Committee proposed a 1-hour maximum of 0.1 ppmv ($140 \mu g/m^3$), which is based on health criteria. The committee has also proposed a 1-hour H_2S incremental limitation of 0.025 ppmv ($35 \mu g/m^3$). State regulations governing H_2S emissions have not been proposed nor have public hearings been scheduled to date. Table 6-8 shows that the results of the model calculations of H_2S ground-level concentrations during normal operation of the plant and steam stacking will be in compliance with the proposed increment of 0.025 ppmv ($35 \mu g/m^3$). Since the background H_2S concentrations are less than 0.048 ppmv ($67 \mu g/m^3$) (see Section 6-1), the ambient H_2S concentration would be less than 0.056 ppmv ($78 \mu g/m^3$) for production, 0.066 ppmv ($92 \mu g/m^3$) for stacking, 0.534 ppmv ($747 \mu g/m^3$) for well blowout, and 0.349 ppmv ($488 \mu g/m^3$) for rupture disk event. Therefore, the proposed AAQS of 0.1 ppmv will be met for normal operation of the plant and steam stacking. The proposed increment and AAQS will be exceeded only in the unlikely case of a rupture disk event or a well blowout. The location of the maximum 1-hour ground level H_2S concentration during production and steam stacking is about 0.6 mile (1 km) north of the plant.

TSP emissions and 24-hour maximum GLCs are shown in Table 6-9. This table also shows the state of Hawaii's 24-hour TSP AAQS value of $100 \mu g/m^3$, which is more restrictive than the comparable federal 24-hour AAQS secondary standard value of $150 \mu g/m^3$. The table shows that, in all cases, the TPC plant meets the strict Hawaii AAQS for TSP since background TSP concentrations are about 20 to $40 \mu g/m^3$ and the maximum ambient TSP concentration that occurs for steam stacking would be less than $52 \mu g/m^3$. The location of the maximum 24-hour ground-level TSP concentration during production and steam stacking is about 0.8 mi (1.3 km) southwest of the plant (Dames & Moore, 1984).

Table 6-8

H₂S EMISSIONS AND MAXIMUM GROUND-LEVEL CONCENTRATIONS

Item	Emissions		Incremental Maximum 1-Hour GLC	1-Hour Proposed State Incremental Limitations
	lb/hr	g/s	ppmv ($\mu\text{g}/\text{m}^3$)	ppmv ($\mu\text{g}/\text{m}^3$)
Production	8.0	1.008	0.008 (11.2)	0.025 (35)
Steam stacking ^(a)	7.3	0.92	0.018 (25)	0.025 (35)
Well blowout ^(b)	195.0	24.6	0.486 (680)	0.025 (35)
Rupture disk event ^(c)	121.0	15.2	0.301 (421)	0.025 (35)

(a) Based on a maximum total steam flow rate of 430,000 lb/hr (54,000 g/s), wells turned down to 65 percent of normal operating capacity, 1,300 ppm H₂S content and an assumed value of 98 percent of H₂S control by the rock muffler system (Dames & Moore, 1984).

(b) Based on a maximum steam flow rate for one well of 150,000 lb/hr (19,000 g/s), 1,300 ppm H₂S content, and no H₂S control.

(c) Based on two active wells connected to the branch line with total steam flow rate of 143,000 lb/hr (18,000 g/s) and 1,300 ppm H₂S. The total steam flow rate in the branch line corresponds to one third of the total steam flow rate to the plant which is 430,000 lb/hr (54,000 g/s). The event would last about 2 hours, until the flow is diverted to a rock muffler and a portable H₂S control system is connected and activated. The wells would be turned down to 65 percent of normal operating capacity in case of a rupture disk event.

Table 6-9

TSP EMISSIONS AND MAXIMUM GROUND-LEVEL CONCENTRATIONS

Item	Emissions		Incremental Maximum 24-hour GLC	24-hour Hawaii AAQS
	lb/hr	g/s	$\mu\text{g}/\text{m}^3$	$\mu\text{g}/\text{m}^3$
Production (a)	0.010	1.3×10^{-3}	0.014	100
Steam stacking (b)	81	10	12	100
Well blowout (b)(c)	43	5.4	6.6	100
Rupture disk event (b)(d)	27	3.3	4.2	100

-
- (a) Based on 0.86 lb/hr (0.108 g/s) of drift droplets, 1,200 ppm of solid particles in steam and 10 cycles of concentration in the cooling tower.
- (b) The emission rate of particulate matter (Y) was estimated from the steam flow rate (X) according to the following equation: $Y = 0.00029 X - 0.42$ where X and Y are in lb/hr (Dames & Moore, 1984).
- (c) Based on maximum steam flow rate for one well of 150,000 lb/hr (19,000 g/s).
- (d) Based on two active wells connected to the branch line.

If the alternative system RT-2, described in Section 2, is used to minimize H_2S emissions, some emissions of nitrogen oxides (NO_x) may occur because of the incineration process. However, the incineration process will be carried out at temperatures low enough to limit NO_x emissions to the range of 0.2 to 0.6 lb/hr, i.e., 0.025 to 0.075 g/s. The corresponding maximum GLC resulting from these emissions will be about 0.0004 ppmv ($0.8 \mu g/m^3$), which is well below the federal annual average standard of 0.053 ppmv ($100 \mu g/m^3$).

Brine from the separators and cooling tower blowdown would have to be ponded during injection well shutdown. H_2S emission from degassing of the pond would be within the allowable limits.

The impact of the cooling tower drift on ambient concentrations of trace elements was estimated based on the trace element content of the steam condensate and the atmospheric dispersion calculation results for GLCs of particulate matter. Results are presented in Table 6-10 for trace elements for which an ambient level goal was reported by Cleland and Kingsbury (1977). The predicted maximum 1-hour GLCs of arsenic, boron, magnesium, and mercury are significantly less than the corresponding ambient level goals of Cleland and Kingsbury (1977). Therefore, no significant air quality impacts are expected to occur due to trace element emissions from the cooling tower draft.

Air quality impacts of radon-222 were also assessed. The radon-222 concentration of the steam was assumed to be 750 pCi/lb (Dames & Moore, 1984). This value is consistent with the values reported by Cox (1980). Assuming a maximum steam flow rate of 150,000 lb/hr (19,000 g/s) and using the results of the atmospheric dispersion calculations for steam stacking, the ambient maximum GLC of radon-222 would be 0.85 pCi/m^3 . This value is significantly less than the federal standard of $3,000 \text{ pCi/m}^3$.

Impacts of Facility Decommissioning on Air Quality

The work required for decommissioning and restoration is similar to that needed for the site development and plant construction phases. However, the

Table 6-10

ESTIMATED EMISSIONS AND MAXIMUM GROUND-LEVEL CONCENTRATIONS
OF TRACE ELEMENTS FROM THE COOLING TOWER DRIFT

Trace Element	Estimated Emissions ^(a)		Maximum 1-Hour Ground-Level Concentration ^(b) ($\mu\text{g}/\text{m}^3$)	Ambient Level Goal ^(c) ($\mu\text{g}/\text{m}^3$)
	lb/hr	g/s		
Arsenic	$<4.3 \times 10^{-6}$	$<5.4 \times 10^{-7}$	$<5.8 \times 10^{-6}$	0.005
Boron	$<4.3 \times 10^{-6}$	$<5.4 \times 10^{-7}$	$<5.8 \times 10^{-6}$	7.4
Magnesium	$<8.7 \times 10^{-7}$	$<1.1 \times 10^{-7}$	$<1.2 \times 10^{-6}$	12
Mercury	$<4.3 \times 10^{-6}$	$<5.4 \times 10^{-7}$	$<5.8 \times 10^{-6}$	0.01

- (a) Emissions of trace elements from the cooling tower drift were estimated based on 0.86 lb/hr (0.108 g/s) of drift droplet, 10 recycles and steam condensate concentrations of trace elements less than 0.5, 0.5, 0.1, and 0.5 ppm for arsenic, boron, magnesium and mercury, respectively.
- (b) Based on the dispersion calculations for TSP (see Table 6-9).
- (c) Cleland, J. G. and Kingsbury, G. L. (1977). Multimedia environmental goals for environmental assessment, Vols. I and II; Report EPA-600/7-77-136a U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

extent of the work will be limited to a shorter period of time. Consequently, air quality impacts will be equal to or less than those described in the subsection on clearing and construction activities.

6.3 PROPOSED MITIGATION MEASURES

Construction Impacts

Well drilling operations will be designed and managed to control leakage of the geothermal steam and to prevent blowouts. The well casing will be designed to minimize the possibility of a well casing rupture. The wellhead and drilling rig will be equipped with blowout preventors to minimize the potential of a blowout. In the unlikely case of a blowout, geothermal fluid including H_2S will vent to the atmosphere until the well is brought under control by injection of water into the wellbore. H_2S emissions will be negligible during drilling operations since a mud drilling technique will be used. During well testing, H_2S emissions will be abated by chemical injection. During well testing, particulate matter emissions will be controlled by the same techniques.

The rotary drilling rig engine exhaust will be controlled by regular maintenance to prevent undue discharges. During clearing and construction, air contaminants will be emitted from the diesel engine exhaust of the construction equipment. Regular maintenance of the engines will prevent undue exhaust discharges. Fugitive emissions in the form of dust from heavy equipment construction activities will vary daily depending on the equipment activity and the weather. During rains, or when the earth is damp, fugitive dust emissions do not occur. During dry periods, the exposed soil in working areas will be sprinkled to control dust, and open-bodied trucks transporting dry materials will be covered. It must be emphasized that the region is quite rainy, with over 0.01 inch of rain per day, on at least 75 percent of the days at Hilo, and the ground can still be damp even on clear days. For these reasons, the temporary occurrences of fugitive dust during construction should be insignificant.

Power Plant and Production Well Operation Impacts

During power plant operation, the principal atmospheric contaminants will be hydrogen sulfide (H_2S) emitted from the cooling tower during normal plant operation, from the rock muffler during steam stacking, and trace metals present in the cooling tower drift.

Emissions of H_2S will be controlled by the plant process equipment. The geothermal steam from the wells will be cleaned and piped to the turbine generator, and the turbine exhausts will flow to the condenser where the spent steam will be condensed.

The power plant design will incorporate multiple safeguards to protect public health, safety, and welfare, and the environment against unexpected impacts. During normal plant operation, noncondensable gases will be separated and injected into the nonreservoir geological strata, i.e., below the groundwater level and above the reservoir level. If this injection system proves to be infeasible, the RT-2 system developed by DOW will be used as an alternative approach to abate H_2S . This approach will also limit H_2S emissions from the cooling tower and the RT-2 system to the appropriate emission levels required to meet the emission standard.

It may be noted that the frequent occurrence of rain will wash out such pollutants as H_2S and TSP from the atmosphere and consequently limit their possible accumulation.

Cooling tower drift will be controlled by demisters with a 0.002 percent release efficiency based on the circulating water flow rate. The drift water droplets, which contain dissolved solids and noncondensable gases in the same low concentrations as the circulating water, will be released from the two cooling towers at a total rate of 0.86 lb/hr (0.11 g/s). This small amount of drift will have no adverse environmental effects.

All normal discharges will meet the concentration limits prescribed by OSHA standards to protect employees, state and federal AAQS to protect the

public, and PSD ambient increment limits to preserve and enhance Class I and Class II locations as appropriate.

The H_2S abatement systems described above apply to normal operating conditions and procedures. Uncontrolled release of geothermal fluids containing 1,300 ppm of H_2S can be expected in case of a rupture disk event. In the case of a rupture disk event, the steam flow will be diverted into a rock muffler, the well flow rate will be reduced to 65 percent of the normal operating capacity, and H_2S control equipment will be activated. This control procedure will be accomplished in less than 2 hours.

Facility Decommissioning Impacts

The required steps to restore the site when the decision has been made to shut down the facility are discussed in Section 2-6. Emissions from intermittent engine exhaust of heavy equipment will be controlled by efficient engine tune-up and maintenance procedures. Particulate matter from fugitive dust sources will be controlled by sprinkling dusty surfaces as necessary. Some of this dust will be controlled naturally since the site is in an area of high rainfall. The decommissioning activities will last only a few months and are not expected to have lasting impacts on the physical environment.

Monitoring

To ensure that all design and environmental criteria are met, the meteorological and air quality monitoring system will be kept in continuous operation. Meteorological monitoring will be conducted at two sites, H_2S monitoring will be conducted at four sites, and Radon-222 measurements will be conducted at one site. The monitoring sites are presented in Figure 6-1. Monitoring will be continuous and measurements will be reported as 1-hour average values.

Meteorological monitoring will be conducted at the Woods Site and at the proposed plant site. Meteorological monitoring at the Woods Site includes wind speed, wind direction, wind direction fluctuation (sigma theta),

temperature, relative humidity, rainfall, and solar radiation. Meteorological monitoring at the proposed plant site includes wind speed, wind direction, temperature, relative humidity, and rainfall.

Continuous ambient measurements of H_2S will be conducted at four sites: Woods, Schroeder, Gilman, and the HGP-A fenceline site. Continuous ambient measurements of Radon-222 will be conducted at the Woods Site.

Section 7
Biological Resources

Section 7

BIOLOGICAL RESOURCES

This section describes the biological resources in the project area and the potential impacts on these resources caused by project development. Char and Stemmerman (1984) developed the baseline biological description, and their study should be consulted for a more detailed discussion of biological resources in the project area.

7.1 ENVIRONMENTAL SETTING

Plants

A total of 240 plant species were found during the course of the botanical field survey of the PGV project area. Of these, 163 (68 percent) were introduced species, 65 (27 percent) were native species, and 12 (5 percent) were of Polynesian introduction. Of the 65 native species recorded, 33 are endemic; that is, they occur naturally only in the Hawaiian Islands. Rare endemic species found in the study area include three Cyrtandra spp., Tetraplasandra hawaiiensis, and Bobea spp. None of these species occurs on the proposed well and power plant sites.

Nine vegetation types found within the study area are described below and shown in Figure 7-1 (an oversized figure found in the back cover pocket). Much of the study area has been modified by human activities and consists of cultivated and fallow fields. About one-third of the study area is covered by the 1955 lava flow. Of the native vegetation types, the open Metrosideros forests occupy the most area. However, this vegetation type is not as species-rich or diverse as some of the other native vegetation types.

Cultivated Areas. The cultivated areas (area C in Figure 7-1) present a mosaic of different crops, stages of cultivation, and various human activities. A network of paved and unpaved roads criss-cross the fields. Papaya (Carica papaya) is the main crop grown in the cultivated areas. A few

banana (Musa X nana) fields, one field of vanda orchids (Vanda teres X V. hookeriana), and one weedy plot of macadamia nut trees (Macadamia ternifolia var. integrifolia) were also observed.

Fallow Fields. Certain portions in the cultivated areas have remained fallow for a long time and can be characterized as open, grassy areas with scattered shrubs (areas C(f) in Figure 7-1). Many of these fallow fields are abandoned sugarcane fields, and sugarcane plants (Saccharum officinarum) are still frequently encountered. Molasses grass (Melinis minutiflora) and California grass (Brachiaria mutica) form the dominant cover.

Closed Metrosideros Forest. Closed Metrosideros forests (area cM in Figure 7-1) can be found on Pu'u Honua'ula, around the large cracks scattered throughout the cultivated areas, in a few parts of the Leilani Estates, and near Pu'u Pilau. These forests are usually found on very old aa lava and are structurally well developed.

The closed Metrosideros forest consists of tall-stature 'ohi'a (Metrosideros polymorpha), 65 to 100 ft (20 to 30 m) tall, with canopy cover greater than 60 percent. The shrub layer, which is 6 to 16 ft (2 to 5 m) tall, usually consists of a mixture of native and exotic species, although in some closed forests the native elements such as kopiko (Psychotria hawaiiensis) may be dominant. The most abundant native species in this layer are the tree ferns, Cibotium glaucum and Cibotium chamissoi. The ground under the closed Metrosideros forest is damp and the rough aa lava blocks are covered with the moss Rhizogonium spiniforme.

The greatest number of native species occur in this vegetation type. Several rare or uncommon native species such as the three Cyrtandra spp., Tetraplasandra hawaiiensis, and the delicate filmy ferns Mecodium recurvum and Gonocormus minutus occur in the damp cracks and crevices of the closed forest.

Open Metrosideros Forest. The open Metrosideros forest (area oM in Figure 7-1) occurs on relatively young, not deeply weathered lava flows. This vegetation type occupies large areas within the study area, such as the

northern section above the Pahoa-Kapoho Road (Halekamahina), the Leilani Estates, and the southern section along the Pahoa-Pohoiki Road.

The open Metrosideros forest is composed of medium-stature, 16 to 50 ft (5 to 16 m) tall, widely spaced trees. Canopy cover varies from 20 to 30 percent. An almost impenetrable mat of uluhe (Dicranopteris emarginata), 3 to 8 ft (1 to 2.5 m) tall, covers the ground. Shrubs of Myrsine lessertiana, Pluchea odorata, guava, and malaban melastome are also widely scattered throughout the uluhe tangle.

Open Metrosideros-Lichen Forest. Part of the 1955 lava flow is included in the study area. The vegetation on the lava flow (area oM(s-L) in Figure 7-1) is characterized by an open (5 to 20 percent cover), low-stature (1- to 4- meter-tall) Metrosideros forest or woodland with a ground cover composed of the whitish-grey-colored lichen, Stereocaulon volcani, and the moss, Campylopus exasperatus. The hairy swordfern, Nephrolepis multiflora, is abundant in the many cracks and crevices that occur in the pahoehoe lava.

Open Metrosideros/Diospyros Forest. This vegetation type (area oMD in Figure 7-1) was observed only on the west slopes of Pu'u Honua'ula. Lama is co-dominant with 'ohi'a, although in some parts of this forest lama forms almost pure stands with only a few scattered 'ohi'a trees. Canopy cover is less than 60 percent. Several large Kolea-lau-niu, trees that are 25 to 30 ft (8 to 10 m) tall with basal diameters of 12 to 14 in. (30 to 35 cm), were found in this vegetation type. Scattered trees of Pandanus odoratissimus are also occasionally found in this forest.

Open Metrosideros-Psidium Forest. This vegetation type (area oM-P in Figure 7-1) can be found in some areas north of the Pahoa-Kapoho Road, on Pu'u Honua'ula and its smaller adjacent pu'u (spatter cone), and in some areas near Pu'ulena Crater.

The open Metrosideros-Psidium forest is composed of medium- to tall-stature 'ohi'a trees, 25 to 65 ft (8 to 20 m) tall, with canopy cover varying from 20 to 50 percent. Scattered trees of lama, kukui (Aleurites moluccana),

guarama (Cecropia obtusifolia), and melochia (Melochia umbellata) are occasionally found. Tall strawberry guava and guava form a distinct subcanopy layer.

All three Cyrtandra species as well as Tetraplasandra hawaiiensis and Bobea sp. were found in this vegetation type.

Mixed Forest. This vegetation type (area mf in Figure 7-1) is a mixture of 'ohi'a and exotic trees: Albizia falcataria, Cecropia obtusifolia, Melochia umbellata, rose apple (Eugenia jambos), and mango (Mangifera indica). A few kukui trees (Aleurites moluccana) are also frequently found in these forests. This vegetation type is often found bordering the roadsides in the study area. Along the Pahoa-Pohoiki Road almost pure stands of Albizia, up to 100 ft (30 m) tall, can be found.

Scrub or Ruderal Community. The scrub or ruderal community (area s in Figure 7-1) is found in areas that are frequently disturbed or have been cleared, such as those along roads and trails, near the power lines east of Lava Tree State Park, and along forest borders. These sites are usually dominated by a number of weedy shrubs and grasses.

This vegetation type may vary from open, grassy areas with scattered shrubs (5 to 10 percent cover) to more or less dense shrub cover (60 to 70 percent), 5 to 20 ft (1.5 to 6 m) tall. Broomsedge, molasses grass, and California grass form the dominant grass cover. The most commonly occurring shrubs are the two Psidium species, pluchea, and Malabar melastome. Several plants of Clidemia hirta, a noxious weed, were found across the road from the Kapoho Electric Substation near pole no. 313.

Fauna

Because of the extent of agricultural disturbance at the project site, the primary species of concern in the Puna District are native birds and mammals.

Birds. Eleven species of nine avian families were observed in the study area. Only two of these species (the Hawaiian hawk and the lesser golden plover) are native; the rest are introduced from outside the islands.

Table 7-1 lists the species present in the study area and their approximate densities, expressed as relative abundances. Table 7-2 presents distributions of bird species by habitats. Table 7-3 lists native species that were not observed during this survey but, based on available literature, are known to be present at lower elevations in the Puna District.

Birds observed in the study area are briefly described below.

Hawaiian Hawk ('I'o). The Hawaiian hawk (Buteo solitarius, Accipitridae), which is endemic to the island of Hawaii, is the only remaining species in a once diverse endemic raptor fauna (Olson and James, 1982). This species is on the Federal List of Endangered Species, though its status has been questioned (M. Scott, USFWS, personal communication). Its breeding range encompasses most of the island of Hawaii including the Puna District, which is an especially dense breeding area. The success of the Hawaiian hawk breeding in Puna is due primarily to the prime agricultural lands extending south and east of the town of Pahoa, which includes the present study area.

Field studies identified in Table 7-4 have shown that the project area around the Pu'u Honua'ula is heavily used by hawks hunting for prey species. This is because of the open nature of this agricultural area and its potential for attracting prey species to discarded fruit and weed seeds.

Five to seven adult and juvenile Hawaiian hawks are estimated to utilize the area within a 1 mi (1.6 km) radius of Pu'u Honua'ula. Figure 7-2 shows the location of Hawaiian hawk sightings from January 31 to February 6, 1984. The results of Hawaiian hawk studies are summarized in Table 7-4. Hawks were most frequently found perching in the small enclaves of native forest adjacent to papaya fields; these areas include Pu'u Honua'ula itself, the adjacent pu'u to the west, and two of the long, narrow Kipukas within the study site. Hawks were also seen in flight, over both forested and cultivated areas.

During the three study periods, four nesting sites were located within a 1-mile radius of the project site. Only one of these nests has been active each year. Nest no. 2 is located about 1 mi (1.6 km) east of the project site

Table 7-1

BIRD SPECIES OCCURRING IN THE PGV STUDY AREA^(a)

<u>Common Name</u>	<u>Species; Family</u>	<u>Status^(b)</u>	<u>Density in Study Area^(c)</u>
Hawaiian hawk, 'I'o	<u>Buteo solitarius</u> ; Accipitridae	Re,E	U
Lesser golden plover, Kolea	<u>Pluvialis dominica</u> ; Charadriidae	Vr	U
Spotted dove	<u>Streptopelia chinensis</u> ; Columbidae	Fl	R
Barred dove	<u>Geopelia striata</u> ; Columbidae	Fl	R
Barn owl	<u>Tyto alba</u> ; Tytonidae	Fr	Occ.
Melodius laughing thrush	<u>Garrulax canorus</u> ; Timaliidae	Fl	U
Japanese white-eye	<u>Zosterops japonicus</u> ; Zosteropidae	Fl	A
Common myna	<u>Acridotheres tristis</u> ; Sturnidae	Fl	A
House sparrow	<u>Passer domesticus</u> ; Ploceidae	Fl	R
Northern cardinal	<u>Cardinalis cardinalis</u> ; Fringillidae	Fl	C
House finch	<u>Carpodacus mexicanus</u> ; Fringillidae	Fl	A

(a) The nomenclature and phylogenetic order follows the American Ornithologist Union Checklist of North American Birds (1982) and Pyle's Preliminary Checklist of the Birds of Hawaii (1977).

(b) Status (Symbols after Pyle (1977), Preliminary Checklist of the Birds of Hawaii, 'Elepaio 37(10):112-121):

Re = Resident species, native, endemic at the species level

Fl = Foreign introduced species, long established and breeding in Hawaii (for more than 25 years)

Fr = Foreign introduced species, recently established and breeding in Hawaii (for less than 25 years)

Vr = Visitor species, breeds elsewhere, regular migrant to Hawaii

E = Currently on the Federal List of Endangered Species

(c) Density (expressed as relative abundance):

Occ. = Occasional

R = Rare

U = Uncommon

C = Common

A = Abundant

Table 7-2

BIRD SPECIES OBSERVED IN VARIOUS STUDY AREA HABITATS^(a)

Common Name	Habitats ^(b)										Total
	A	B	C	D	E	K1	K2	K3	K4	F	
Hawaiian hawk, 'I'o				5				1	2		8
Lesser golden plover, Kolea			4	1	3						8
Spotted dove	1		1							1	3
Barred dove					1						1
Barn owl		1									1
Melodius laughing thrush	2	1	2	4		1	2	1		3	16
Japanese white-eye	5	11	26	33	3	3	1	12	5	8	107
Common myna	5	6	7	14	20			9	3		64
House sparrow			3								3
Northern cardinal	2	1	8	13	1	2	5	2	4		38
House finch	<u>11</u>	<u>7</u>	<u>21</u>	<u>41</u>	<u>9</u>	<u>1</u>	<u>2</u>	<u>6</u>	<u>9</u>	<u>1</u>	<u>108</u>
Total	26	27	72	111	37	7	10	31	23	13	357

(a) The nomenclature and phylogenetic order follows the American Ornithologist Union Checklist of North American Birds (1982) and Pyle's Preliminary Checklist of the Birds of Hawaii (1977).

(b) Habitats:

- A = Large-stature exotic forest near Lava Trees State Park and along Pahoa-Pohoiki Rd.
- B = 'Ohi'a forest north of Pahoa-Kapoho Rd.
- C = 'Ohi'a forest, Leilani Estates
- D = Pu'u Honua'ula and smaller pu'u to its immediate southwest
- E = Papaya fields (active and inactive) and other agricultural areas in study site
- K1 = Small Kipuka (crack) 1/3 mile northeast of Pu'u Honua'ula
- K2 = Small Kipuka (crack) 1/2 mile east/southeast of Pu'u Honua'ula
- K3 = Large Kipuka (crack) 1 mile east of Pu'u Honua'ula
- K4 = Large Kipuka (crack) 1/4 mile west/northwest of Pu'u Honua'ula
- F = Pu'ulena Crater

Source: Char and Stemmerman, 1984

Table 7-3
POTENTIAL UNOBSERVED
BIRD SPECIES IN THE
PGV STUDY AREA

Common Name	Species; Family	Low Elevation (HAVO) (ft)	Density	Factors Affecting Study Site Distribution ^(a)
Short-eared owl, Pueo	<u>Asio flammeus sandwichensis</u> ; Strigidae	1,200	Rare	H,C
Hawaiian thrush, 'Omao	<u>Phaeomis obscurus obscurus</u> ; Turdidae	1,600	1-10 birds/40 ha	H,C,D ^(b)
'Elepaio	<u>Chasiempis sandwichensis</u> <u>sandwichensis</u> ; Musicapidae	400	11-20 birds/40 ha	H ^(c) ,C
'Amakihi	<u>Loxops virens virens</u> ; Fringillidae	50	Less than 1 bird/40 ha	H ^(d) , S ^(e)
'O'u'	<u>Psittirostra psittacea</u> ; Fringillidae	ca. 2,100	Rare (one individual) ^(f)	H,R,D,C
'Apapane	<u>Himatione sanguines</u> ; fringillidae	400	21-60 birds/40 ha	H,R ^(g)

(a) Distribution factors: H = Habitat alteration
C = Competition
D = Disease
R = Resource availability
S = Sampling technique

(b) The thrush occurs commonly well below zones of mosquito infestation, indicating the secondary importance of disease in determining this species' distribution.

(c) High densities of this species are associated with high structural diversity of habitat which is generally lacking in the Pu'u Honua'ula area.

(d) 'Amakihi prefer open dry scrub and forested areas to more mesic habitats (Conant 1980, personal observation). They have been found in the Malama Ki Forest Reserve (Puna) at an elevation of 250 feet (Berger, 1983).

(e) Conant (1980) indicates greater-than-usual difficulty in detecting this species from 10:00 a.m. to 2:00 p.m. Because of limited field time available, much of the censusing for birds occurred during these hours.

(f) Only one observation at this low elevation is cited in conant's NPS survey (1980). This species is probably found in lower Puna only as a result of the wide dispersion tendency of these birds from their distributional center, Ola'a Tract at HAVO, 4,000 feet. This species requires species habitat parameters (see Berger, 1983) and undisturbed forests. It will probably not occur in habitats such as those around Pu'u Honua'ula, which have been considerably altered.

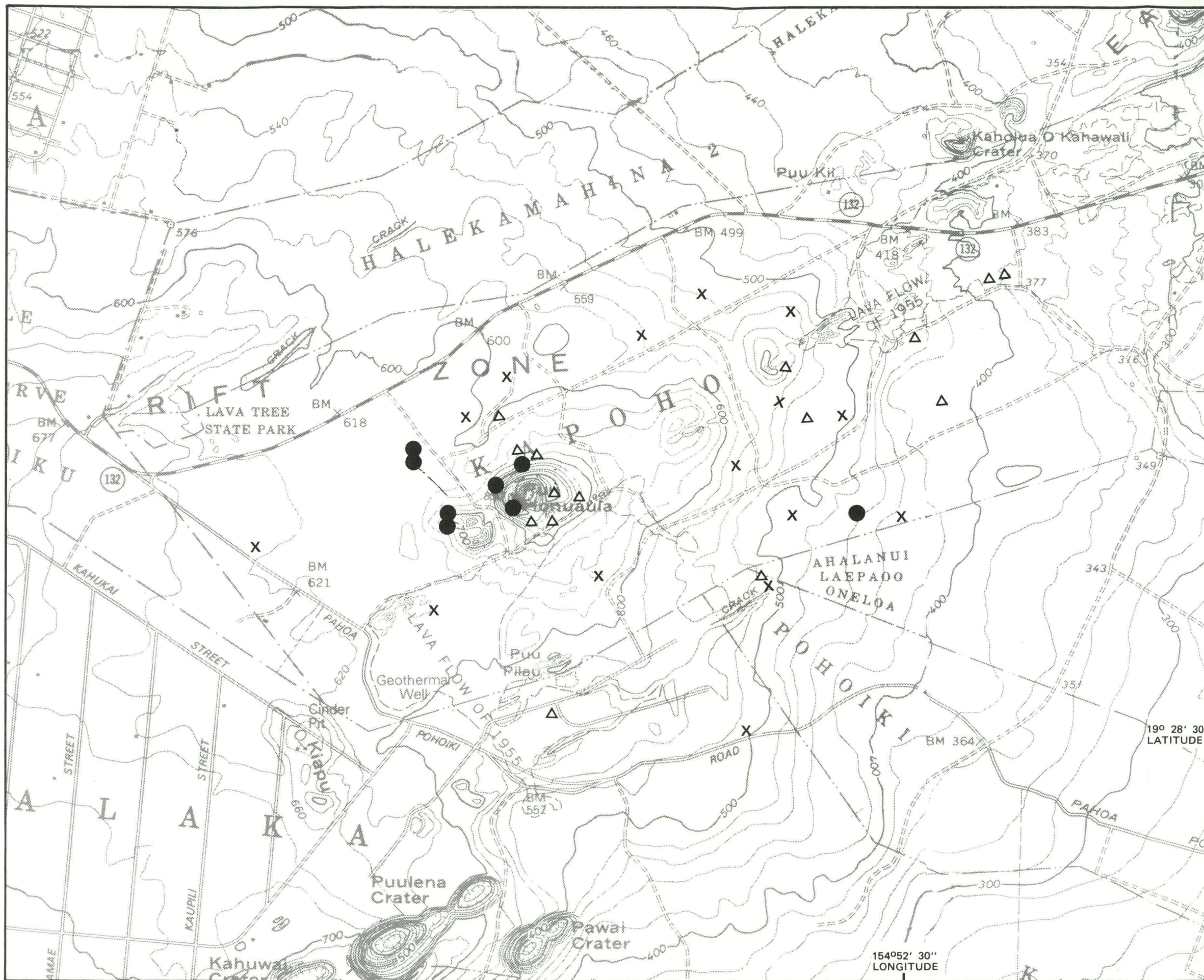
(g) 'Apapane appear to require a certain minimum density of 'ohi'a or a minimum level of nectar availability (Carpenter and MacMillen, 1976; Conant, 1980, personal observation). Presence of 'Apapane in the Pu'u Honua'ula area (if at all) may be sporadic due to fluctuation of resource levels. Reduction of habitat quality in the study area due to invasion of exotic plants may also be a factor affecting this species' distribution. (The latter would affect 'Amakihi and 'Elepaio in a similar manner.)

Table 7-4

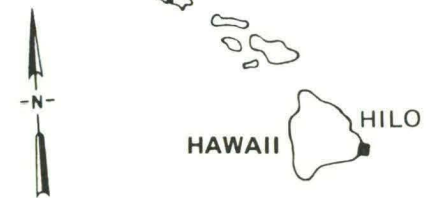
SUMMARY OF HAWAIIAN HAWK STUDIES

<u>Survey Dates</u>	<u>Total Hawk Sightings</u>	<u>Estimated Total Individuals</u>	<u>Total Nests</u>	<u>Active Nests</u>	<u>Survey Author, Year</u>
January 1, 1984 - February 6, 1984	8	4	-	-	Char and Stemmerman, 1984
June 14, 1984 - June 29, 1984	-	7	4	1	M. Stemmerman, 1985
June 4, 1985 - July 15, 1985	23(a)	5 to 7	3	1	J. Jeffries, 1985
April 28, 1986 July 15, 1986	18(b)	5 to 7	3	1	J. Jeffries, 1986

-
- (a) Does not include hawk sightings at nest sites.
 (b) Census method changed.

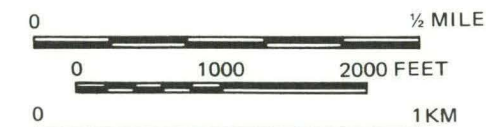


MAP LOCATION



- SIGHTINGS (1984 SURVEY)
- X SIGHTINGS (1985 SURVEY)
- △ SIGHTINGS (1986 SURVEY)

SCALE
CONTOUR INTERVAL 20 FEET



SOURCE: U.S.G.S., 1980, 1981a, 1981b

PUNA GEOTHERMAL VENTURE PROJECT HONOLULU, HAWAII

Figure 7-2
LOCATION OF HAWAIIAN HAWK
SIGHTINGS, 1984, 1985 AND 1986

BECHTEL GROUP INC.	JOB. NO.	DRAWING NO.	REV.
	15722		

and was active all 3 years. A single nestling was raised in 1985, and another was raised in 1986. No hawk nests have been found on Pu'u Honua'ula. Prey fed to the young hawks included rodents and small birds (Jeffries, 1985, 1986).

In June 1984, Stemmerman (1985) noted adult hawks adding nesting material to nest no. 2 but never observed eggs or young. Apparently, Hawaiian hawks do not breed every year but will maintain a nest and often an alternative nest within their territory. This second nest could be used if the first proved inadequate. Although no activity has been seen at a second nest site 330 ft (100 m) west of the active nest (nest no. 2), this well-kept nest is most likely an alternative nest maintained by the active breeding pair.

Although only one active nest was found in the area, the frequency of hawk sightings suggests that the number of suitable nesting sites within the area is limited, but hawks are nesting in nearby areas and foraging over the study area.

Land clearing for agricultural purposes, although detrimental to nesting sites, has allowed for an increase in food availability for hawks and thus an increase in the number of hawks utilizing the area from adjacent territories.

Although indirect human disturbance is noted to have only a minor effect on nestlings, prolonged loud noise or close human activity could be detrimental to reproductive success. The active nest, less than 330 ft (100 m) from a producing papaya field, is constantly exposed to human disturbance. Bulldozers, field workers, and tractors are constantly in the area and in the view of the young and adults. Only when the noise is excessive (the sound of a bulldozer operating nearby or a helicopter flying low and overhead) do the hawks become agitated, but apparently because of continued human activity they have become, to some extent, habituated to this disturbance.

Lesser Golden Plover. The lesser golden plover, or Kolea (Pluvialis dominica, Charadriidae), is a shorebird that breeds in Siberia and Arctic North America. Wintering populations arrive in the Hawaiian Islands in late August and leave in March and April. On their wintering grounds, individual

birds are often territorial and site-tenacious, returning to the same location year after year (Brunner, personal communication, 1984). The Kōlea were widely distributed in fairly small numbers throughout the study area. They are most commonly found in agricultural fields and open areas and, in smaller numbers, on subdivision roads.

Spotted Dove. The spotted dove (Streptopelia chinensis, Columbidae) was found in very low densities in forested portions of the study area, particularly in the Leilani Estates and adjacent areas, and in the vicinity of Lava Trees State Park.

Barred Dove. The barred dove (Geopelia striata, Columbidae) was observed only once in the study area, in papaya fields north of the Pu'u Honua'ula well sites. This species (like the preceding one) is primarily a seed-eating bird (Schwartz and Schwartz, 1949; Berger, 1983) and requires a source of drinking water. This factor probably plays an important role in determining the low abundance of both of these species in the study area.

Barn Owl. The barn owl (Tyto alba, Tytonidae) is a relatively recent introduction to the Hawaiian Islands; the first birds were introduced to the Hamakua region of the island in 1958. The primary food items of this species in the Hawaiian Islands are small mammals, particularly mice and small rats (Tomich, 1971). One individual of this species was seen soon after dusk on February 11, 1984, adjacent to the Pahoa-Kapoho Road. The barn owl probably occurs in low densities throughout the agricultural portions of the study area, although its nocturnal habits prevent accurate density estimation or determination of its distribution.

Melodius Laughing Thrush. The melodius laughing thrush (Garrulax canorus, Timaliidae) was found in low numbers in forested portions of the study area, apparently preferring exotic vegetation to native forest. This bird was most frequently observed in exotic stands of forest on Pu'u Honua'ula, in the Leilani Estates, and in the vicinity of Pu'ulena Crater.

Japanese White-Eye. The Japanese white-eye (Zosterops japonicus, Zosteropidae) was one of the most common species in the study area. It was found throughout all habitats censused. Lowest densities were seen in papaya fields and other agriculturally modified habitats. Higher densities were found in closed forests (both native and exotic), with highest numbers occurring in the Leilani Estates and on Pu'u Honua'ula. This species is an omnivore, which has provoked much speculation on its possible role in the local extinction of native forest birds through dietary competition (Banko, 1978; Banko and Banko, 1976).

Common Myna. The common myna (Acridotheres tristis, Sturnidae) was also particularly abundant throughout the study area. Unlike the Japanese white-eye, it showed a marked preference for open areas such as inactive papaya fields and areas under cultivation. In forested regions, mynas were invariably found in cleared areas (e.g., roads) or adjacent to forest edges. This species is known to be commensal with man and does not often stray from developed areas.

House Sparrow. Another commensal species, the house sparrow (Passer domesticus, Ploceidae), was found in very low numbers only in the Leilani Estates section of the study site. Berger (Kamins, 1978) did not find this species in his earlier survey of the Pohoiki region, and it may be newly established here.

Northern Cardinal. The northern cardinal (Cardinalis cardinalis, Fringillidae) was sighted in relatively low numbers throughout the study area. This species showed a distinct preference for forested areas (very common at Pu'u Honua'ula, less so in Leilani Estates), particularly those with some exotic plant cover. It was sighted on only one occasion in cultivated fields.

House Finch. The house finch (Carpodacus mexicanus, Fringillidae) was common to abundant in all habitats within the study area and was often found in large flocks of up to 40 birds. Though primarily a seed eater, the house finch is renowned for its predilection for papaya and other soft fruits

("papaya bird" is a widespread common name for the species), which explains, to some extent, its abundance in the study site.

Potential Unobserved Bird Species in the Study Area. Several species of birds are known to occur in other portions of the Puna District (especially areas at elevations below 2,000 ft [600 m]) but were not seen during field observation in the project study area despite the presence of suitable habitat.

Table 7-3 shows data from censuses in the Kalapana Extension of Hawaii Volcanoes National Park, lowest known elevations from census counts, and approximate abundance at that elevation (Conant, 1980). Data from Hawaii Volcanoes National Park should be considered to be from a moderately undisturbed ecosystem. (Factors H, C, and D on Table 7-3 are all present to some extent but are not as severe as in the Pu'u Honua'ula area, which has been impacted by various kinds of human activity for a number of years.)

Mammals. Signs of non-native mammals were common in the study area. Mongooses were seen and heard consistently in all agricultural habitats, and were especially common in old fields where there was a high density of shrubs and weeds for cover. One feral cat was seen in papaya fields adjacent to Pu'u Honua'ula. Rats and mice were evident in active papaya fields due to their gnawing of ripe fallen papaya. Four species of rodents may be found in these habitats (Kramer, 1971). Mus musculus, Rattus rattus, and Rattus exulans are occasionally found in fields, while Rattus norvegicus is found most frequently within 500 ft (150 m) of human habitations or other structures (Eskey, 1934, cited in Kramer, 1971). There was no evidence of feral pig activity in the study area.

There were no observations of the native hoary bat in the study area. This species preferentially forages along forest edges or over bodies of water (Baldwin, 1950); there is probably a suitable habitat for this species in the Pu'u Honua'ula area. However, there are no published records of bats in the Puna District.

7.2 ENVIRONMENTAL IMPACTS OF THE PROPOSED ACTION

The discussion below addresses clearing and construction impacts, operation impacts, and impacts of facility decommissioning on the biological environment.

Clearing and Construction Impacts

The well sites and proposed power plant and facilities sites are situated on fallow fields, scrub vegetation, or cultivated areas. Exotic, weedy species make up the dominant vegetative cover in the uncultivated areas, and papaya plants occur extensively throughout the cultivated areas. The native species that do occur on the proposed well and power plant sites are not designated as rare, threatened, or endangered on the federal or state lists, and are found throughout the Puna District and neighboring districts. It is projected that construction at the proposed sites will have no significant impact on the total island populations of the plant species present at these sites.

Temporary construction disturbances to mammal and bird populations will be insignificant. The nearest Hawaiian hawk nest, about 1 mi (1.6 km) east of the project site, should not be significantly affected by noise or other construction activities.

Operation Impacts

Emissions from plant operation that may affect regional vegetation are:

- o Gases and condensation drift from the cooling tower
- o Steam vented during periodic well maintenance
- o Steam stacking
- o Well blowout
- o Rupture disk event

Liquid discharges from the plant will be injected into a deep well, thus posing no hazard to vegetation or wildlife.

Noncondensable gases that may be present in geothermal fluids include:

- o Carbon dioxide (CO_2)
- o Hydrogen sulfide (H_2S)
- o Ammonia (NH_3)
- o Nitrogen (N_2)
- o Hydrogen (H_2)
- o Methane (CH_4)
- o Ethane (C_2H_6)
- o Helium (He)

Carbon dioxide and hydrogen sulfide usually predominate, and the other gases usually occur at minor levels (Dames & Moore, 1984). Studies of the HGP-A well have found high H_2S content, low CO_2 content, and no NH_3 relative to other geothermal reservoirs; however, during operation most gases will be stripped from the steam and injected.

Data collected during yearly vegetation monitoring and plant tissue analysis at the HGP-A site and adjacent areas have shown no significant increases in toxic emissions such as mercury (Hg) or arsenic (As) (Ecotrophics, 1981a, 1981b, 1982). These findings, however, are based only on short-term observations.

Maximum H_2S concentrations from normal and accident/upset conditions are not expected to affect vegetation or wildlife adversely, based on a literature review of H_2S environmental effects. Short-term H_2S exposure, resulting from a well blowout, has caused vegetation damage to H_2S -sensitive plant species in concentrations as low as 5 ppm ($7,000 \mu\text{g}/\text{m}^3$) (Lodgepole Blowout Inquiry Panel, 1984). This injury level is significantly above the 0.49 ppm ($680 \mu\text{g}/\text{m}^3$) maximum GLC expected from the project's worst case accident release (see Table 6-9). Long-term or continuous exposure to H_2S has resulted in vegetation damage to H_2S -sensitive plant species in concentrations as low as 0.3 ppm ($420 \mu\text{g}/\text{m}^3$) (Thompson and Kats, 1978).

This injury level is significantly above the 0.008 ppm (11.2 $\mu\text{g}/\text{m}^3$) maximum GLC for normal plant operations (see Table 6-9). The predicted H_2S GLCs are also not expected to affect birds or mammals adversely, based on a literature review of H_2S exposure effects on wildlife (Siegel, et al., 1986; New Norway Scientific Committee, 1974).

A direct, relatively short-term negative impact on nearby vegetation could result if the emission control systems break down. However, this damage would occur only if steam is vented for an extended time and if the trade winds (which normally disperse the steam very quickly) are weak or absent.

Impacts of Facility Decommissioning

During facility decommissioning there will be minor impacts on the biological environment due to the increased use of heavy equipment and increased activity. These impacts, which will be similar to the construction impacts previously described, are expected to be minor and short-term. After the facilities are removed, the area will be restored to support the best alternative land use.

7.3 PROPOSED MITIGATION MEASURES

The discussion below addresses the mitigation of construction impacts, operation impacts, and impacts of facility decommissioning on the biological environment.

Construction Impacts

No significant direct impacts to the biological environment are expected during construction because the land has been previously disturbed by agricultural and volcanic activity.

Prolonged loud noise (such as low flying helicopters) or other close human activity may potentially impact the nesting of the endangered Hawaiian hawk ('I'o). The only known active hawk nest is about 1 mi (1.6 km) east of the plant site and should not be significantly affected by the plant construction or operation.

Operation Impacts

The only way power plant operation can affect biota is through discharges to the environment, such as liquid and gaseous fluids, thermal discharge, trace emissions of escaping H_2S , and noise. Available scientific evidence indicates that the ambient concentrations produced by these discharges will be too low to cause any significant impacts on biological resources. Liquid and gaseous fluids will be injected into the geologic formations; excess thermal energy will be discharged to the atmosphere at the cooling towers; and trace emissions of H_2S remaining after abatement and the noise of operation are too low to affect biological resources.

The Hawaiian hawks in the area should not be significantly affected by plant operation. They are accustomed to human activity in the papaya fields, and the active nests are about 1 mi (1.6 km) from the plant site. The low levels of human activity at the plant and well sites and the limited geographic extent of these activities should not significantly disturb the Hawaiian hawks.

No toxic emissions such as mercury or arsenic are expected at the power plant. However, a long-term monitoring program designed to detect any changes in the vegetation caused by emissions will be continued during operation of the power plant.

Impacts of Facility Decommissioning

No significant impacts on the biological environment due to facility decommissioning are expected. During the decommissioning process, the existing topography will be restored and the area will be revegetated.

Section 8
Noise

Section 8

NOISE

8.1 ENVIRONMENTAL SETTING

The following describes existing site conditions, noise ordinance, and existing site noise levels.

Existing Site Conditions

The area around the PGV project site is a mixture of light to dense vegetation, consisting of papaya orchards, woodlands, and other natural vegetation, and barren lava. Included in the PGV site are two volcanic pu'u (hills), Pu'u Honua'ula and an unnamed pu'u, which rise about 150 ft (45 m) above the surrounding land. South and southeast of the site, the land has been subdivided into 1-acre homesites. Most of these are vacant. There are about one dozen residences located within 1 mi (1.6 km) of the site. The nearest homes are about 1/2 mi (0.8 km) to the east and to the south of the site. Land uses in the project vicinity are discussed in Section 3. The site is exposed to the normal northwest tradewinds, which blow 9 months out of the year and frequently exceed 12 mph (Burgess, 1980) with gusts up to 20 mph.

Noise Ordinance

Currently, there is no known noise ordinance with numerical limits applicable to the site. However, the County of Hawaii Planning Department has developed Geothermal Noise Level Guidelines from a study of noise in the Puna District (Darby-Ebisu and Associates, Inc., 1981). The study was based on U.S. Environmental Protection Agency noise criteria and may be applied to this project as the basis for use permit conditions. These guidelines consider 55 dBA during daytime (7:00 a.m. to 7:00 p.m.) and 45 dBA during nighttime (7:00 p.m. to 7:00 a.m.) as satisfactory sound levels for residential areas. The allowable noise limit for impact noise (noise of short duration, typically less than 1 second, and caused by impacts of pipes, tools, etc.) is 10 dBA higher than the overall limits for daytime and nighttime. The allowable noise

levels may not be exceeded more than 10 percent of the time in any 20-minute period.

Existing Site Noise Levels

An environmental noise survey was conducted at the PGV site to determine current ambient (background) noise levels during weekday periods. Two battery-powered noise monitoring systems were used to measure the ambient noise levels for 24-hour periods at four locations. The survey was conducted during early September 1986.

Monitoring Locations. Four noise monitoring locations, chosen in conjunction with Bill Burkhard of Alpha Micro Systems, who is a consultant to the state of Hawaii, were used in this survey and are shown in Figure 8-1. Two of the locations were on residential properties located south and southwest at approximately 1/2 and 1 mi (0.8 and 1.6 km), respectively, from the PGV proposed power plant site. These resident locations are:

- o Brees Station, lot 54, Lanapuna Gardens, Lauone
- o Gilman Station, residence, Kaupili Street

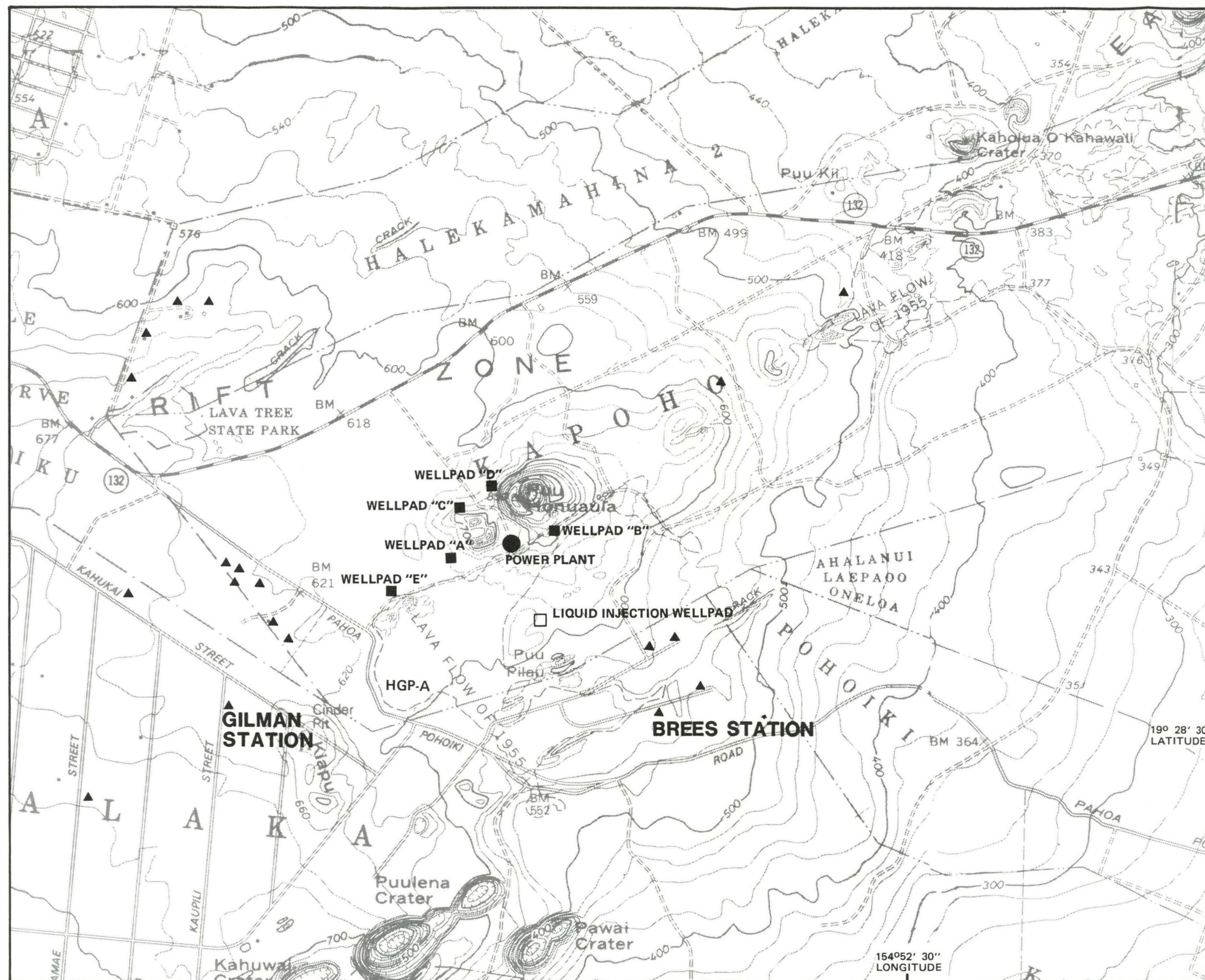
The two remaining monitoring locations were on the PGV site, one at Wellpad A and the other at Wellpad B.

The instrumentation and procedures used for this environmental noise survey are described in the appendix.

Noise Descriptors

The noise descriptors (L_{90} and L_{eq}) used for the purpose of this survey are defined below:

- o L_{90} is the A-weighted sound pressure level that is exceeded 90 percent of the time. The specified time period is 1 hour. The L_{90} is commonly used as an indicator of the ambient (background) noise level.
- o L_{eq} is the equivalent sound level, which is the energy average of the A-weighted sound pressure level. The specified time period is 1 hour. The energy average is the constant noise level for an hour that has the same average energy as the actual fluctuating level during the hour.



Summary of Results. The hourly L_{90} and L_{eq} A-weighted sound pressure levels measured during a nominal 24-hour period at each monitor location are tabulated in Table 8-1.

The existing noise environment during the survey period on and around the PGV site was fairly quiet throughout much of the daytime and nighttime periods. However, during moderate wind (6 mph or greater) and moderate to heavy rain conditions, the hourly L_{90} noise levels increased by 19 dBA. These wind and rain conditions occurred during 1 day of measurement between 2:00 and 7:00 a.m. at the Gilman Station. During this period, the hourly L_{90} noise level ranged from 48 to 51 dBA (exceeding the county noise guidelines of 45 dBA). The noise increase was due to rain falling on broadleaf vegetation and wind blowing through nearby trees. During this survey period, early morning rains were observed each day and localized rain showers of short duration during daytime hours.

The range of hourly L_{90} and average L_{eq} sound levels measured at off-site resident station and on-site locations during day and nighttime periods are presented in Table 8-2. Daytime is defined from 7:00 a.m. to 7:00 p.m. and nighttime from 7:00 p.m. to 7:00 a.m.

The prevalent noise during daytime hours is from distant and local traffic, wind, birds, and insects. Noise from operation of the HGP-A Facility, located on Pahoa-Pohoiki Road, just south of the PGV site, was barely audible at the PGV on-site monitoring locations (Wellpads A and B), and inaudible at the two off-site resident monitoring stations.

8.2 ENVIRONMENTAL IMPACTS OF THE PROPOSED ACTION

The following describes impacts of construction, traffic, and drilling operations noise.

Impacts of Construction, Traffic, and Drilling Operations Noise

Development of the geothermal steam field will occur in stages. For each stage, characteristic noise sources can be identified, the duration of which will vary from one drill site to another. Certain noise sources, such as

Table 8-1

TWENTY-FOUR-HOUR NOISE MONITORING DATA

Monitoring Locations	On-Site Wellpad A		Off-Site Resident Brees Station		On-Site Wellpad B		Off-Site Resident Gilman Station	
Time Period	23 Hours		24 Hours		24 Hours		24 Hours	
Hour Ending	L_{90} (dBA)	L_{eq}	L_{90} (dBA)	L_{eq}	L_{90} (dBA)	L_{eq}	L_{90} (dBA)	L_{eq}
12:00	-	-	-	-	-	-	-	-
13:00	-	-	36	51.0	-	-	-	-
14:00	36	38.1	35	43.9	-	-	36	50.3
15:00	36	37.7	35	43.3	33	54.4	34	43.7
16:00	36	37.5	34	42.7	34	36.8	32	46.7
17:00	37	45.5	35	44.6	34	42.8	32	50.2
18:00	38	50.0	33	43.2	36	40.2	35	39.1
19:00	36	40.5	32	34.2	38	40.8	40	47.7
20:00	36	39.8	35	36.7	41	43.5	50	53.1
21:00	36	38.7	34	36.6	36	39.8	39	42.8
22:00	37	37.8	34	35.8	35	38.6	39	41.2
23:00	36	41.1	34	36.0	38	41.6	38	41.8
0:00	36	41.9	35	36.8	38	41.0	41	44.5
1:00	37	40.1	35	37.0	39	41.9	42	44.3
2:00	37	40.6	35	37.2	37	39.7	44	49.4
3:00	37	40.8	35	37.0	39	40.8	48	50.1
4:00	36	41.8	35	37.1	39	41.2	49	51.9
5:00	38	40.8	34	36.6	41	42.6	51	53.2
6:00	39	42.7	34	36.4	38	41.7	50	52.2
7:00	37	44.2	35	46.4	36	46.8	43	47.3
8:00	35	39.0	34	43.9	39	42.5	35	43.8
9:00	35	63.4	34	46.8	37	44.3	36	43.3
10:00	36	41.1	34	48.4	33	42.8	35	42.9
11:00	36	64.0	37	43.6	32	35.0	34	43.8
12:00	36	36.7	40	46.3	33	40.0	33	43.0
13:00	-	-	-	-	33	37.2	34	51.2
14:00	-	-	-	-	34	39.3	-	-

Table 8-2

RANGE OF HOURLY L_{90} AND AVERAGE L_{eq} SOUND LEVELS

	<u>On-Site Locations</u>		<u>Off-Site Locations</u>	
	<u>Wellpad A</u> <u>(dBA)</u>	<u>Wellpad B</u> <u>(dBA)</u>	<u>Brees</u> <u>Station</u> <u>(dBA)</u>	<u>Gilman</u> <u>Station</u> <u>(dBA)</u>
Hourly L_{90} Sound Levels				
Daytime	35 to 38	32 to 39	32 to 40	32 to 40
Nighttime	36 to 39	35 to 41	34 to 35	38 to 51
Hourly Average $L_{eq}^{(a)}$ Sound Levels				
Daytime	37 to 64	35 to 54	34 to 51	39 to 51
Nighttime	38 to 44	39 to 47	36 to 46	41 to 53

(a) Rounded to the nearest dB level.

vehicular traffic, will continue at varying levels for the life of the project. Expected noise sources include the following:

- o Construction noise, which is associated with earthmoving and construction equipment used during road-building, wellpad construction, and pipeline laying, and building erection. This noise will occur primarily during the initial stages of the project.
- o Traffic noise, which is generated by trucks and automobiles travelling to and from the project. Traffic noise will occur throughout the life of the project.
- o Drilling operations, which will occur mostly toward the beginning of the project and at each wellpad location as it is developed.
- o Well-testing and bleeding noise, which occurs primarily at the beginning of the project, but also sporadically throughout the life of the project.

These noise sources are discussed in the following paragraphs.

Construction Noise. During the initial stages of the project, power equipment used to construct roads, wellpads, the power plant, and pipelines will generate noise. Construction will normally be restricted to weekday (Monday through Friday) daylight hours. The primary noise is expected to be caused by large diesel-powered equipment.

Backup alarms, which are standard safety features of construction equipment, produce a loud beeping sound that, by law, must be clearly audible above the construction noise itself. The distinctive beeping noise will often be audible. The use of these alarms will be intermittent.

Power plant construction noise will be caused by heavy equipment, such as bulldozers, graders, trucks, compressors, portable generators, and pumps. Neither pile driving nor blasting is planned. The octave band noise levels used in predicting construction equipment noise are based on typical construction equipment noise levels and are shown in Table 8-3. Noise from impacts of pipes and other miscellaneous short-duration noise sources may cause higher short-term noise levels.

Table 8-3

EQUIPMENT NOISE LEVELS USED TO PREDICT PLANT
CONSTRUCTION NOISE
(Sound Pressure Levels in dB at 50 ft)

<u>Equipment</u>	<u>Octave Band Center Frequency (Hz)</u>								<u>dBA</u>
	<u>63</u>	<u>125</u>	<u>250</u>	<u>500</u>	<u>1,000</u>	<u>2,000</u>	<u>4,000</u>	<u>8,000</u>	
Bulldozer	113	101	85	76	73	65	63	60	90
Portable generator	110	98	82	73	70	62	60	58	87
Scraper	114	102	86	77	74	66	64	61	91
Excavator	113	101	85	76	73	65	63	60	90
Warning horn	-(a)	-	103	99	93	89	85	-	100
Off-highway hauler	117	105	89	80	77	69	67	64	94
Air compressor	112	100	84	75	72	64	62	59	89

(a) Noise level for this frequency was not obtainable or significant.

Source: Bolt, Beranke, and Newman, 1977.

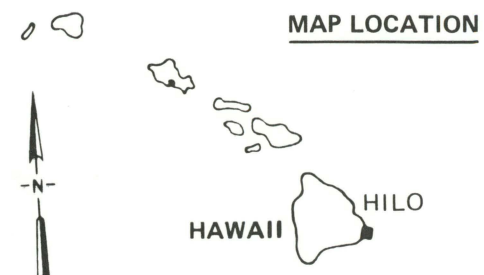
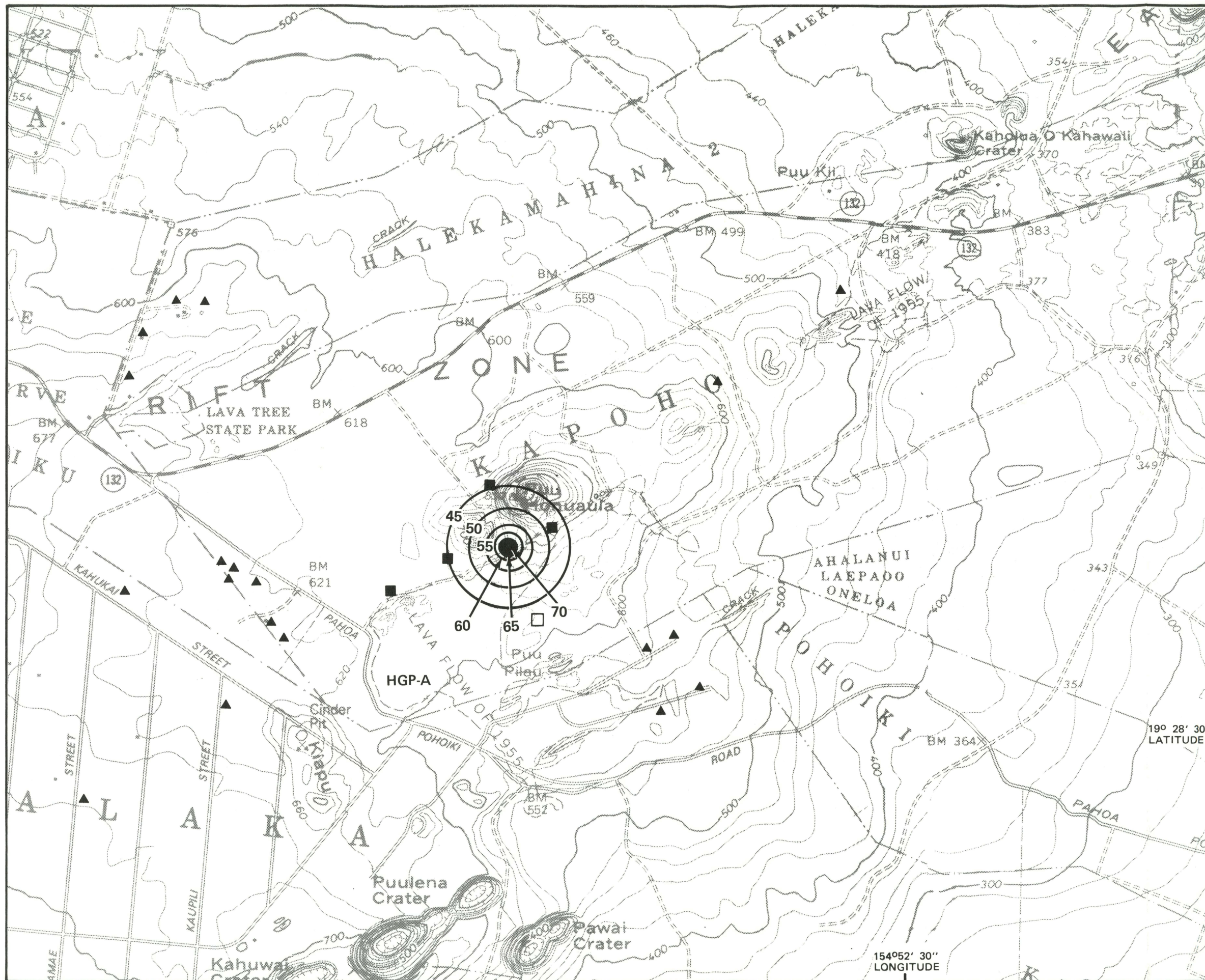
Figure 8-2 shows the predicted noise levels due to construction in the power plant area. Construction noise should not significantly affect nearby residents. All noise predictions in this document include the effects of atmospheric attenuation only; other attenuations, such as foliage, barriers, and terrain effects are neglected. During favorable atmospheric conditions, foliage and terrain attenuation can cause significantly lower noise than is shown, particularly in the sound shadow zones shown on the figure.

Wellpad and road construction will require heavy equipment similar to that used for power plant construction. Noise levels will usually be less than those during construction of the power plant, since fewer pieces of heavy equipment are required. However, these noises will occur throughout the project area. Preparation of drill sites may require several weeks of work, typically not continuous, so that the total elapsed time may be several months. Wellpads A and B are already completed.

Traffic Noise. Based on the Transportation Study for The Geysers Geothermal Resource Area, the expected total of vehicle trips for a typical geothermal steam field and power plant development (110 MW) project during construction and well drilling is 70 vehicle round trips per day (California Energy Commission, 1981). The PGV plant is approximately one-fourth the size of The Geysers plant, and the actual traffic will probably be half of this total.

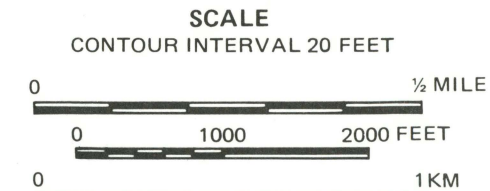
Noise levels for the access road traffic were estimated using the federal highway noise prediction model (U.S. Federal Highway Administration, 1977). It was assumed that the average speed of the traffic was 30 to 40 mph and that the vehicles were travelling up a grade. At a distance of 200 ft (160 m) from the roadway, the hourly average traffic noise (L_{eq}) was calculated to be between 30 and 40 dBA.

Drilling Operations Noise. In drilling the geothermal wells, mud is used as the circulation medium. The primary noise sources will be the mud circulation equipment, generators, and the engines, located on the drilling rig. The mud-drilling phase may last up to 2 months.



- LEGEND:**
- POWER PLANT
 - PRODUCTION WELLPAD
 - LIQUID INJECTION WELLPAD
 - ▲ HOMES NEAR PROJECT SITE

NOISE LEVELS ARE IN dBA
 SHADED AREA IS WHERE NOISE LEVELS COULD BE LOWER DUE TO TERRAIN BARRIER EFFECTS



**PUNA
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 HONOLULU, HAWAII**

**Figure 8-2
 PREDICTED NOISE LEVEL CONTOURS
 FOR PLANT CONSTRUCTION
 AND SHUTDOWN**

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Air drilling (drilling with air as the circulating medium instead of mud) will be used only for remedial well work which may occur 2 to 4 years after the initial mud drilling. The noise from drilling with air is expected to be higher, due to the air compressor engines and the discharge of air and rock cuttings. Finally, when steam is encountered, the noise of escaping (venting) steam will be added to the air compressor noise. However, a good muffling system will reduce steam noise to a level 10 dB above that of the air compressors. It is possible to further reduce routine steam-venting noise levels essentially to that of the air compressors. The air drilling phase may last up to 10 days.

Drilling noise predictions were based on noise measurements made near a specially quieted Barnwell drill rig (without any steam-venting noise) at Puna, Hawaii, and on pipe impact and air compressor noise measured at The Geysers in California. The octave band noise levels used in predicting drilling noise levels are listed in Table 8-4. It is assumed that the steam mufflers in use will silence steam-venting noise to a level 10 dB above the specially quieted Barnwell rig noise levels shown in Table 8-4. Use of an inefficient steam muffler would result in steady drilling noise levels higher than these. Efficient portable or stationary muffler designs are available. During well testing, noise may at times be slightly higher than that during drilling. The use of effective portable or permanent rock mufflers designed for this purpose can attenuate well testing noise significantly.

Figures 8-3 through 8-8 show the predicted steady noise levels at the site due to drilling with air compressors (worst case condition) and muffled steam-venting noise at Wellpads A, B, C, D, and E, and the liquid injection wellpad, respectively. (Noise from grading or other drill site construction activities is not included.) In this report, all predicted noise levels include the effects of atmospheric attenuation only. Other attenuations such as foliage and terrain effects are neglected, therefore giving a worst case analysis. The sound shadow zones on each figure show where the noise levels will often be lower due to barrier effects of the terrain. It was assumed that drilling will occur at only one well at a time. Actual noise levels will

Table 8-4

NOISE LEVELS USED TO PREDICT
DRILLING NOISE
(Sound Pressure Levels in dB at 50 Feet)

Item	Octave Band Center Frequency (Hz)								dBA
	<u>63</u>	<u>125</u>	<u>250</u>	<u>500</u>	<u>1,000</u>	<u>2,000</u>	<u>4,000</u>	<u>8,000</u>	
Steady noise of specially quieted Barnwell drill rig, no steam venting noise ^(a)	76	76	77	73	70	63	60	52	75
Steady noise of thoroughly muffled steam during drilling	86	86	87	83	80	73	70	62	85
Maximum noise of pipe impact ^(c) (intermittent source)	-(b)	-(b)	79	88	90	88	76	-(b)	93
Steady noise from two air compressors ^{(d)(e)} with enclosures	83	83	80	73	65	62	60	58	75
Steady noise from one diesel generator ^(a)	56	52	57	58	60	59	53	46	64

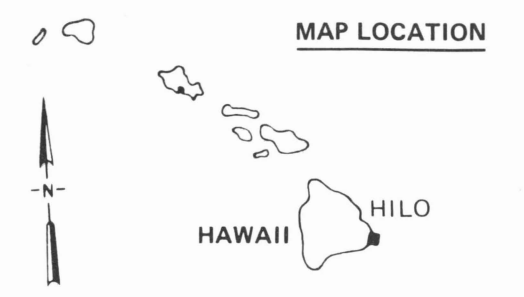
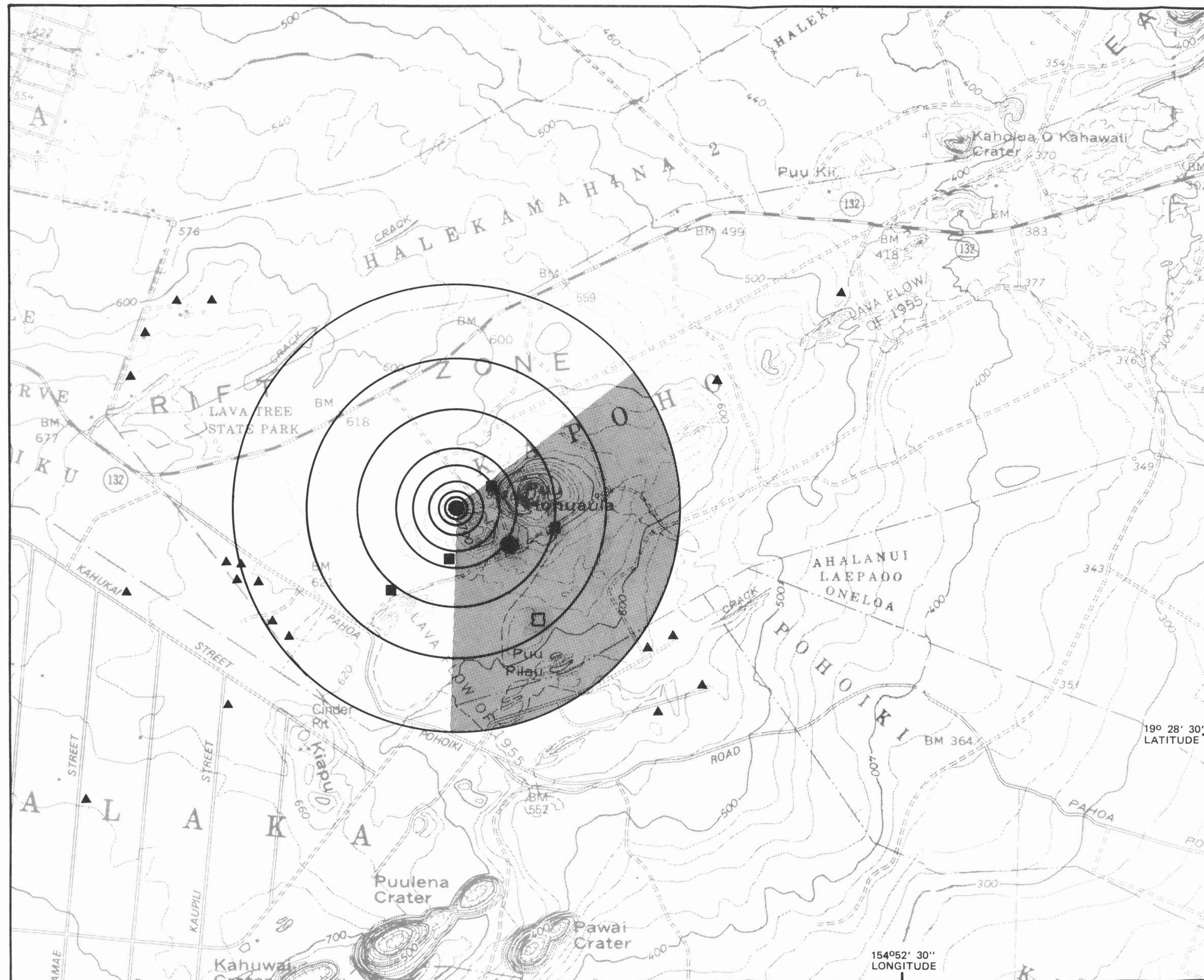
(a) Darby-Ebisu, 1982.

(b) Noise levels at this frequency would not contribute significantly.

(c) Consultants in Engineering Acoustics, 1981.

(d) Ibid.

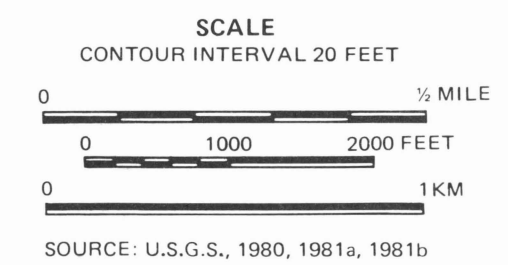
(e) Air compressors not used during mud drilling.



- LEGEND:**
- POWER PLANT
 - PRODUCTION WELLPAD
 - LIQUID INJECTION WELLPAD
 - ▲ HOMES NEAR PROJECT SITE

NOISE LEVELS ARE IN dBA

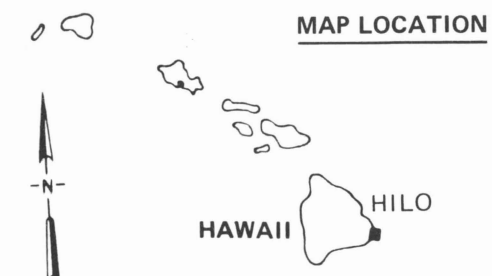
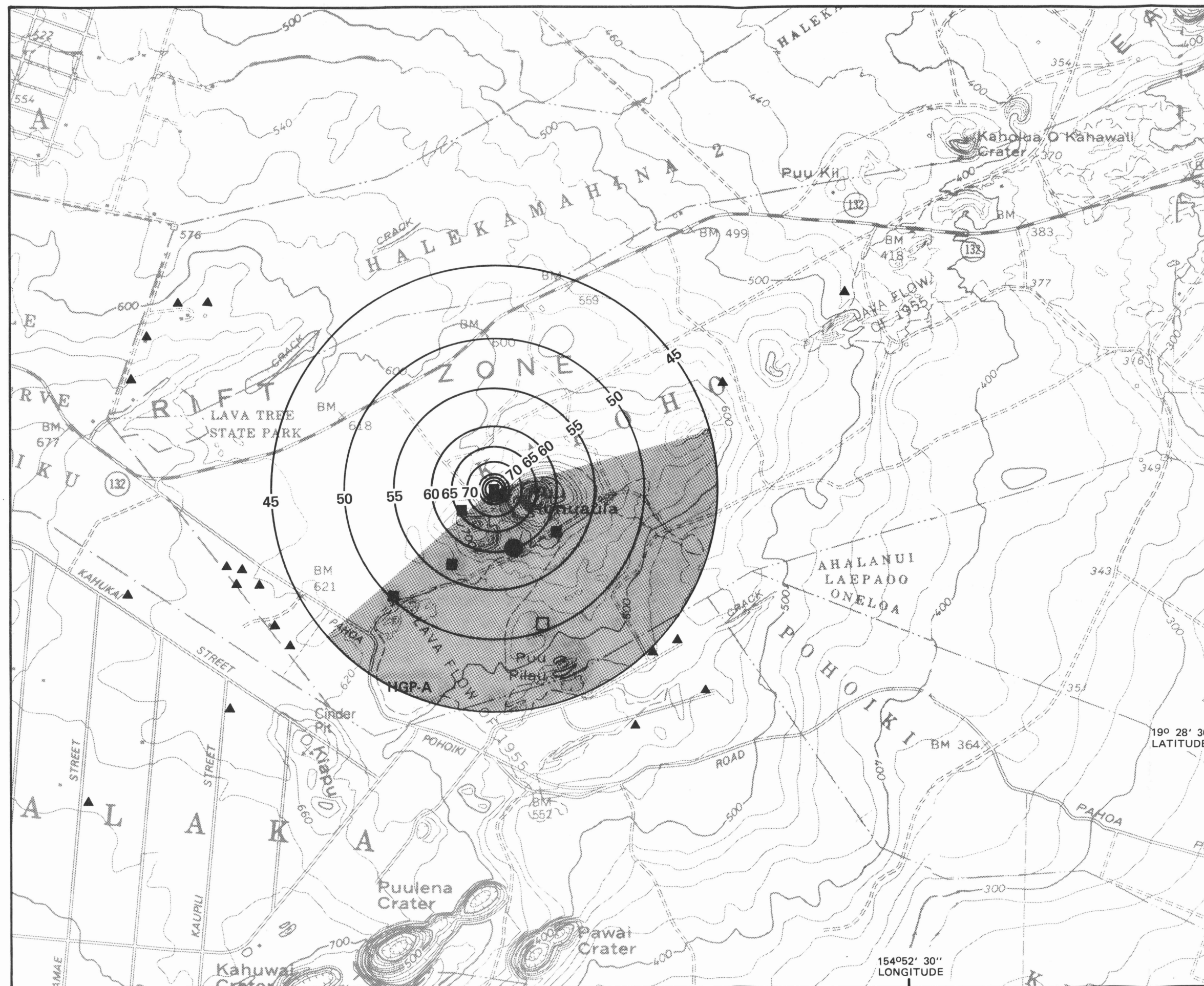
SHADED AREA IS WHERE NOISE LEVELS COULD BE LOWER DUE TO TERRAIN BARRIER EFFECTS



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**Figure 8-5
PREDICTED CONTOURS OF
CONTINUOUS NOISE FOR
DRILLING AT WELLPAD "C"**

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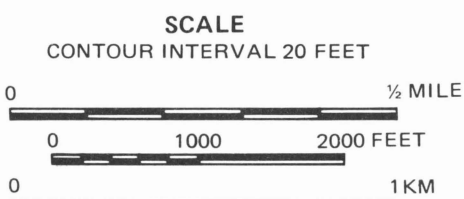


LEGEND:

- POWER PLANT
- PRODUCTION WELLPAD
- LIQUID INJECTION WELLPAD
- ▲ HOMES NEAR PROJECT SITE

NOISE LEVELS ARE IN dBA

SHADED AREA IS WHERE NOISE LEVELS COULD BE LOWER DUE TO TERRAIN BARRIER EFFECTS

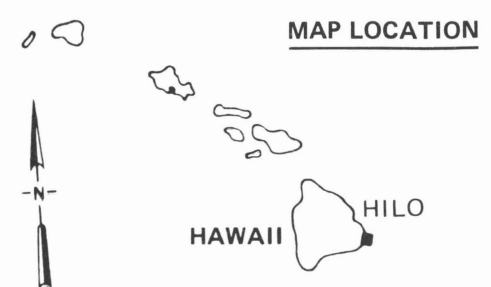
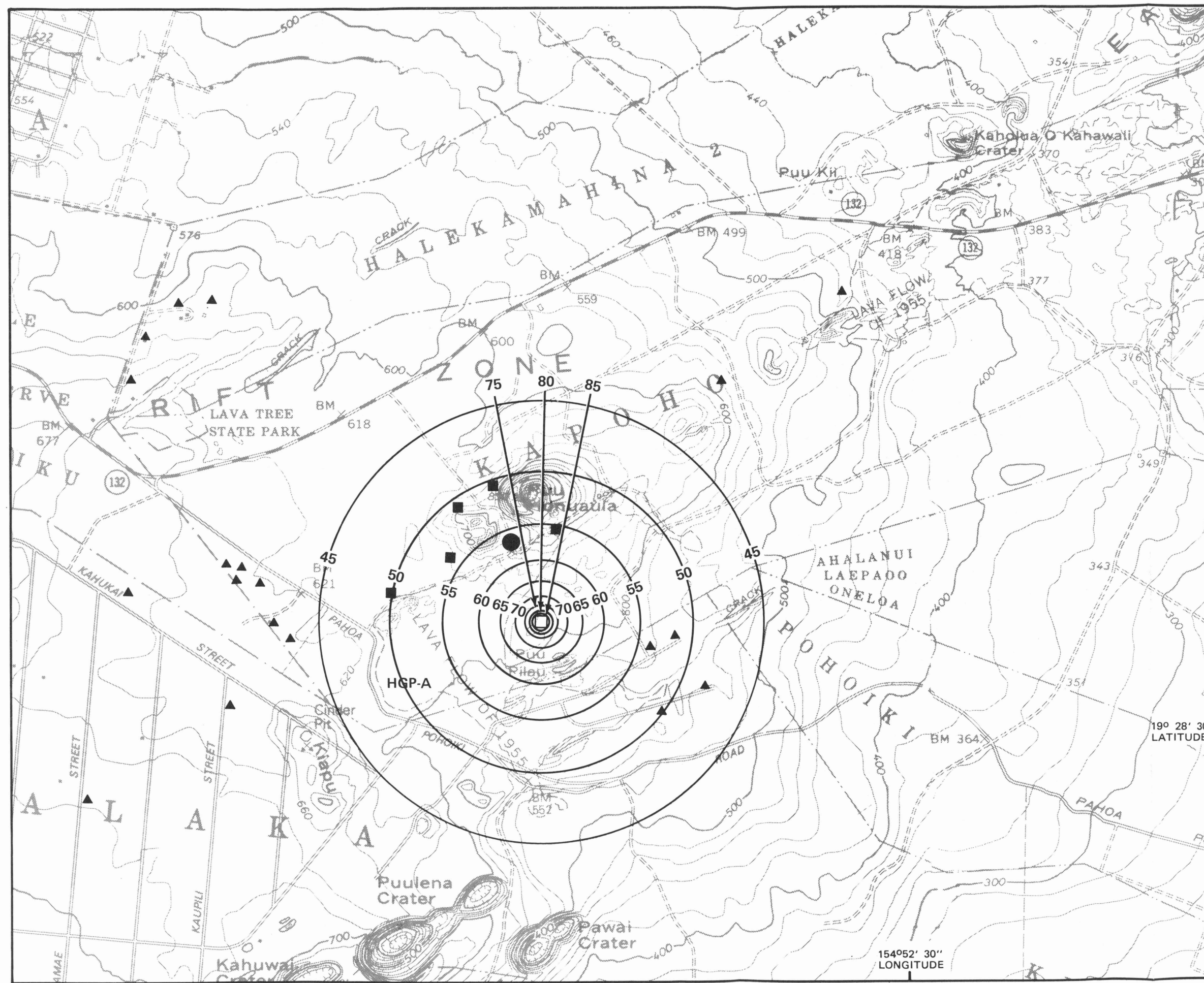


SOURCE: U.S.G.S., 1980, 1981a, 1981b

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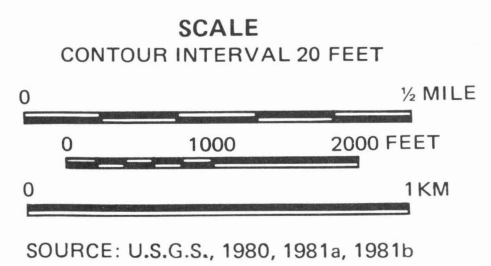
Figure 8-6
PREDICTED CONTOURS OF
CONTINUOUS NOISE FOR
DRILLING AT WELLPAD "D"

BECHTEL GROUP INC.	JOB. NO.	DRAWING NO.	REV.
	15722		



- LEGEND:**
- POWER PLANT
 - PRODUCTION WELLPAD
 - LIQUID INJECTION WELLPAD
 - ▲ HOMES NEAR PROJECT SITE

NOISE LEVELS ARE IN dBA



**PUNA
GEOTHERMAL VENTURE PROJECT
HONOLULU, HAWAII**

**Figure 8-8
PREDICTED CONTOURS OF
CONTINUOUS NOISE FOR
DRILLING IN STEAM AT THE
LIQUID INJECTION WELLPAD**

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	15722		

depend on steam muffler efficiency (a less efficient muffler than assumed will result in noise levels up to 20 dB higher). It is also assumed that the drill rig is thoroughly silenced to the noise levels on Table 8-3 by use of high-quality mufflers, effective noise shielding, and enclosures.

The pipe impact noise levels used are maximum levels and only occur momentarily. Therefore, the predicted noise levels shown are the peaks; continuous noise levels are lower. However, rough pipe handling could cause higher peak noise levels.

Short-term drilling activities may produce temporarily high noise levels. For example, extremely noisy compressed air releases occur when the drill pipe is separated without first depressurizing it through an effective muffler. Several upsets can occur during drilling that would result in very noisy unmuffled steam or air releases. Steam is normally prevented from escaping by a one-way check valve, located within the drill pipe, often called a float valve. If this valve fails or cannot be used for technical reasons, or if the drill pipe is broken above the float valve, and if the top of the drill pipe is opened (while pulling pipe sections out of the hole, for example), then high-pressure and noisy steam releases will occur on or above the rig floor. However, such events rarely occur. Certain well casing placement operations also result in noisy steam releases for a period of hours.

Cementing the wellbore is another short-term noise. Cementing noise is estimated to be 10 dB above steady drilling noise, but it is highly dependent on the noise controls used on the cementing truck. No short-term noise sources are included in Figures 8-3 through 8-8.

Well Testing and Bleeding Noise. After a well is drilled, it will be tested to determine its capacity and other characteristics. Testing may initially require 7 days; however, it is the objective of the project to reduce this to 24 to 48 hours of flow. Testing may be performed continuously or intermittently for the required period. Normally, testing will utilize an effective rock muffler which quiets steam discharge to 55 dBA or less at the lease boundary. Venting wells directly to the atmosphere (unmuffled), which

is the safest and most expedient method, is the most powerful geothermal noise source, and was partly responsible for the noisy reputation of early geothermal development. In the present project, the duration of unmuffled venting will be minimized as much as possible. During emergencies, when it would be unsafe not to vent, or in case of an accident, levels could temporarily be as high as 125 dBA at 50 feet (Burgess, 1980).

One of the loudest short-term noises may occur when the pipelines are cleaned out and pressure-tested prior to production. The cleanout procedure consists of intermittent venting steam during daylight only for several hours at high velocity from the wells to openings in the pipeline where it is released directly to the atmosphere. The procedure normally occurs once for each section of pipeline. Typically, there are only one or two major cleanouts per steam field, which may consist of several sessions over several days. Depending on flow requirements, noise levels due to cleanouts and pressure tests may be as low as those for steady drilling or as high as those for high-pressure unmuffled well venting (Table 8-4).

Plant Operation Noise. Noise during operation will be generated by the following sources:

- o Turbine-generators
- o Cooling towers
- o Circulating water pumps and motors
- o H₂S abatement system
- o Steam ejectors
- o Steam stacking (controlled venting through rock mufflers)
- o Steam gathering system (including valves)

These power plant noises and the operation of the steam-gathering system are discussed in the following paragraphs. The transmission lines and transformers are not included in this report and are not discussed here.

The octave band noise levels for the sources used in predicting operational noise are shown in Table 8-5. Figure 8-9 shows the maximum noise level contours during normal plant operation. Nearby residents should not be significantly affected by the noise of plant operation.

In developing the noise contours shown in Figure 8-9, it was assumed that the total noise of plant operation would not exceed the cooling tower noise by more than 2 dB. This estimate of source noise assumes effective noise controls will be applied to the turbines, some piping, the H₂S abatement system, the steam ejector, and possibly other equipment. It also assumes effective suppression of noise from the steam release facility and the use of efficient rock mufflers in the steam release facility. Because a highly efficient rock muffler will be used when it is necessary to release steam to the atmosphere, noise levels during stacking episodes will not be higher at existing residences than during normal plant operation. The piping and valves will also require special attention during design and may require thermal/acoustical lagging in places.

Unmuffled steam venting to the atmosphere occurs only for well cleaning, in emergencies, in case of accident, or when safety prohibits use of a muffler. Steam venting with a duration of 2 to 4 hours will occur when a well is brought on-line and possibly again when conditions dictate remedial work or well cleaning is necessary, which is expected to be infrequent. Remedial work and well cleaning will be planned during daylight and when the acoustical attenuation characteristics of the atmosphere due to wind and temperature gradients (Burgess, 1980) are favorable. Residents will be notified prior to remedial (venting) work and well cleaning. Therefore, unmuffled venting to the atmosphere is not included in the predictions of operational noise. Unmuffled well-venting could create noise levels of up to 125 dBA at a distance of 50 ft (15 m), and of 50 to 83 dBA at a distance of 1 mi (1.6 km) (Burgess, 1980).

Occasional noise sources include separator drains and condensate drippings (if vented without muffling), unmuffled rupture disks (only when flowing steam after rupture), and well venting (such as during master valve replacements). Wells should rarely have to be vented directly to the atmosphere during steam

Table 8-5

NOISE LEVELS USED TO PREDICT
NOISE FROM PLANT OPERATION
(Sound Pressure Levels in dB at 50 Feet)

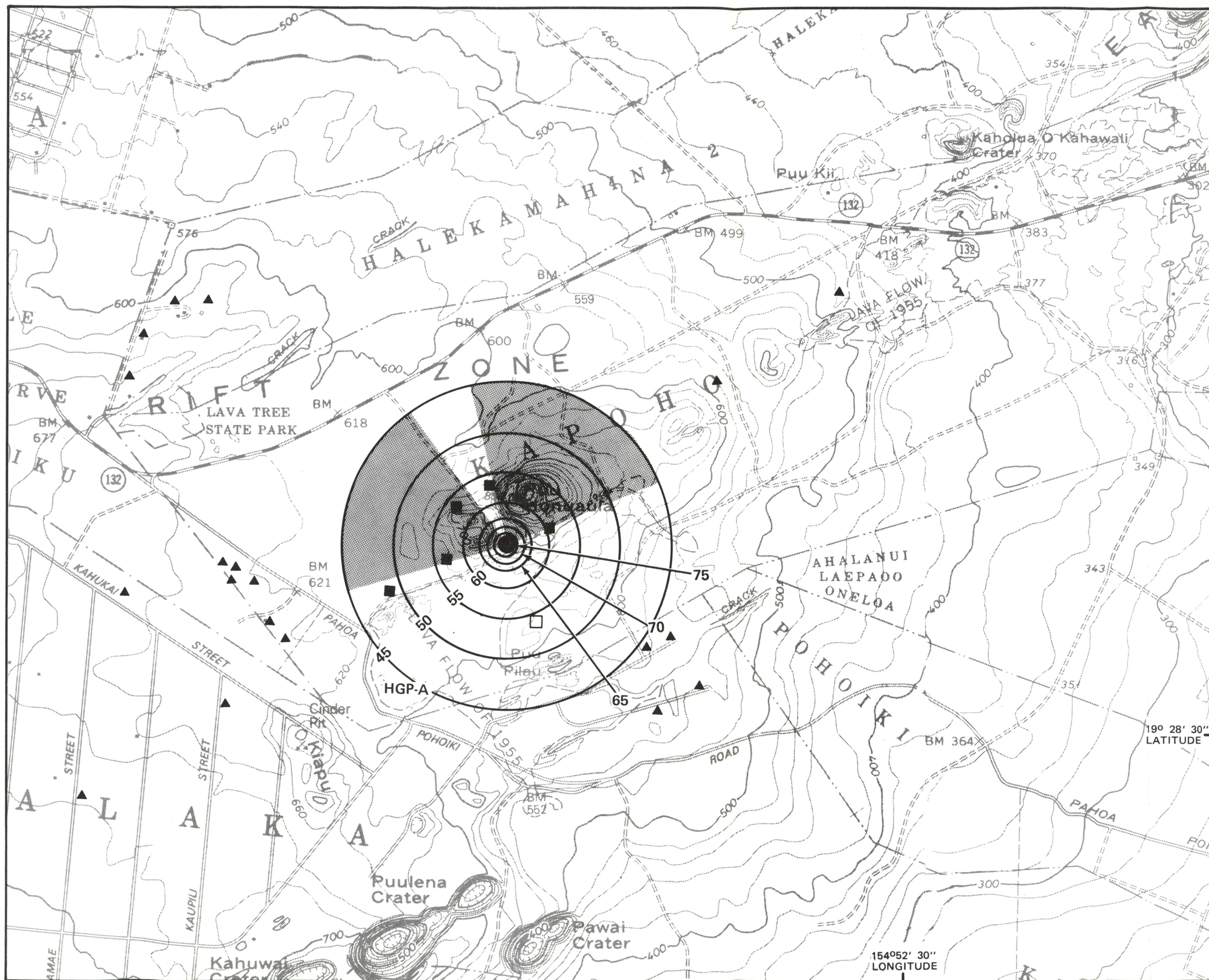
<u>Item</u>	<u>Frequency (Hz)</u>								<u>dBA</u>
	<u>63</u>	<u>125</u>	<u>250</u>	<u>500</u>	<u>1,000</u>	<u>2,000</u>	<u>4,000</u>	<u>8,000</u>	
Turbine ^(a)	69	69	65	63	60	58	53	45	66
Cooling tower, per cell ^(a)	78	78	75	72	68	65	62	54	74
H ₂ S abatement to injection well (compressor)	89	83	79	93	91	80	70	60	94
Steam ejector (1-inch insulation) ^(c)	--(b)	74	73	73	73	75	76	69	81
Flow noise in steam pipes ^(d)	51	52	50	51	48	46	43	33	53

(a) Edison Electric Institute, 1978.

(b) Noise level for this frequency was not obtainable or significant.

(c) Consultants in Engineering Acoustics file data

(d) Bechtel In-House Computer Prediction, including 20 dB of silencing.



MAP LOCATION

HAWAII HILO

LEGEND:

- POWER PLANT
- PRODUCTION WELLPAD
- LIQUID INJECTION WELLPAD
- ▲ HOMES NEAR PROJECT SITE

SCALE

CONTOUR INTERVAL 20 FEET

0 1000 2000 FEET

0 1/2 MILE

0 1KM

19° 28' 30" LATITUDE

154° 52' 30" LONGITUDE

SOURCE: U.S.G.S., 1980, 1981a, 1981b

**PUNA
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HONOLULU, HAWAII**

**Figure 8-9
PREDICTED CONTOURS OF
NOISE FROM NORMAL
POWER PLANT OPERATION**

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production. However, such occasional noise sources can cause complaints, particularly if they occur at night. Regardless of plans, it may not always be feasible to release steam through mufflers during maintenance procedures. The frequency and duration of any unmuffled steam releases are difficult to estimate, though they should be infrequent.

The design pressure drop across the control valve at the wellhead will be 16 psi and will not cause any significant noise. However, if this pressure drop becomes sizeable (between 75 psi and 150 psi), the noise from the control valves could be 40 to 45 dBA at 0.5 mile, depending on valve type and size, piping configuration, and insulation (Consultants in Engineering Acoustics, 1981). Such distinctive valve noise will then be clearly audible at residential locations, even in the presence of most background noises of the same A-weighted noise level.

Noise from water droplet impingement at pipeline bends is expected to be a minor noise source (Burgess, 1980).

Power Plant and Well Decommissioning Noise. The major noise sources during plant decommissioning and abandonment will be from the same heavy construction equipment used for plant construction. The octave band noise levels used to predict construction noise (see Table 8-3) also reflect decommissioning noise, since the equipment and the noise sources are substantially the same. (See Figure 8-2 for predicted plant shutdown noise levels.) The noise levels have been adjusted for atmospheric attenuation, but not foliage, barrier, or terrain effects. Momentary noise from collapsing structures during demolition may be plainly audible above the general noise of construction equipment. In the shaded areas of Figure 8-2, the noise levels may be lower as a result of terrain barrier effect "sound shadows."

No blasting is planned during plant shutdown and abandonment.

8.3 PROPOSED MITIGATION MEASURES

The following discussion covers proposed mitigation measures for drilling rig noise, construction noise, operation noise, and plant decommissioning

noise. With these noise mitigation measures, and the operating precautions discussed in Section 8.2, no significant noise impact on biological resources or nearby residents is expected.

Drilling Rig Noise

Continuous drill rig noise will be reduced by:

- o Using residential-grade exhaust mufflers
- o Placing or constructing an acoustic enclosure around the drill rig engines and other noisy mechanisms
- o Silencing engine radiator air inlets and outlets

All of these methods have been successfully used during drilling on this site by TPC.

Operations that may cause higher noise or impacts of pipes, such as pulling the drill bit out of the hole for replacement (roundtripping), will be scheduled for the daylight hours as much as possible.

Silencers and/or acoustic enclosures will continue to be used on all auxiliary equipment, such as diesel engines, generators, and pumps. If steam venting is necessary during drilling operations, effective mufflers will be used on the drill rig, such as a rock muffler or a high-efficiency steam vent silencer. The best mufflers will reduce steam release noise to the same level as that produced by the air compressors or quieter. Other measures to reduce noise include orienting drilling equipment to direct maximum noise away from residences and silencing noisy steam vents.

Construction Noise

Construction equipment, including auxiliary equipment such as portable generators and air compressors, will have highly effective exhaust mufflers that do not compromise engine operation. Construction activities will also be limited to daytime hours, and backup alarms will be limited to the minimum legal limits.

Operation Noise

Controls that will be used to reduce operating (field and plant) noise are listed below:

- o Insulate noisy pipes and valves with acoustically effective material.
- o Install silencers on pressurized steam outlets, including rupture disks.
- o Acoustically insulate any steam ejectors.
- o Arrange the plant layout to shield residents from cooling tower noise.
- o Use quiet fans, motors, and baffles for the cooling towers.
- o Enclose, muffle, or acoustically insulate any noisy equipment.
- o Use acoustical insulation and/or enclosures for the turbine generator.
- o Baffle or muffle ventilation openings to control noise emissions from the turbine hall building.
- o Schedule noisy maintenance during daylight hours.

Plant Decommissioning Noise

Noise mitigation measures for plant decommissioning and abandonment will be generally the same as those for construction. Residential mufflers will be used on all equipment exhausts, and enclosures provided for all portable equipment, such as air compressors, generators, and pumps. Plant and wellfield dismantling will be done during daytime hours.

Section 9
Public Health and Safety

Section 9

PUBLIC HEALTH AND SAFETY

This section discusses the inherent risks associated with geothermal development in general and the PGV project in particular. To present the information as clearly and cohesively as possible, the normal division of environmental setting and impact analysis were not used in this section only.

9.1 PUBLIC HEALTH AND SAFETY RISKS

In general, anticipated project-related public health risks for H_2S and other risks in the near vicinity (0.6 mi [1 km]) of the project can be characterized as follows:

- o Continuous exposure to very low levels of H_2S released from the cooling tower during operation
- o Temporary exposure to higher levels of H_2S and other geothermal gases resulting from the planned open venting or an accidental well blowout during construction, or accidental release of gases from a ruptured pipe during operation or other low probability event
- o Possible increase in traffic accidents resulting from increased construction-related traffic
- o Possible risk of spills of toxic chemicals in transport to the site

In addition, construction and operation employees at the plant will be exposed to:

- o Normal risks associated with working at an industrial facility plus additional exposure to high-temperature and high-pressure conditions
- o Low levels of H_2S released from the cooling tower and leaks from other sources
- o Possible arsenic exposure during plant operation and maintenance
- o Risks associated with transport, storage, and handling of hazardous chemicals (i.e., NaOH) used at the site

Hydrogen Sulfide Releases

Hydrogen sulfide gas (H_2S) is the major public health concern associated with the development of geothermal power and is typically found in areas of volcanic geothermal activity. H_2S is a colorless gas that at low concentrations has an offensive, rotten egg odor. Although it is not generally a serious health risk, it can cause respiratory poisoning at high concentrations, acting primarily as a systemic poison (American Conference of Governmental Industrial Hygienists, 1980). Estimates of minimum odor threshold levels vary considerably; however, the distinctive smell of H_2S may be detectable by humans even at very low levels (0.00047 ppmv) (Walton and Simmons, 1978). Table 9-1 summarizes the health effects of exposure to H_2S at various concentrations.

The occupational exposure limits recommended by the American Conference of Governmental Industrial Hygienists (ACGIH) for H_2S are:

- o Threshold limit value (TLV) 10 ppmv
- o Short-term exposure limit (STEL) 15 ppmv

Various studies have indicated eye irritation and odor problems (nuisance or annoyance) at minimum concentrations ranging from 5 to 100 ppmv. The OSHA ceiling or Maximum Permissible Exposure Limit (PEL) is 20 ppmv. The TLV value of 10 ppmv is for workers working a 40-hour week exposed at the plant.

For residents of the surrounding area, who may be exposed for up to 24 hours per day, 7 days per week, it is therefore necessary to adjust the TLV downward to derive an Estimated Permissible Concentration (EPC). This can then be compared with the estimated project emission maximum ground-level concentrations (GLCs) to assess health impacts. Two adjustment factors are used to establish the EPC (Dourson and Stara, 1983):

- o To adjust to a 24-hour day, 7-day week, the TLV value is divided by 4.2 (168 hours/40 hours).
- o To account for sensitive subgroups within the population (children, older people, and individuals with respiratory or other illnesses), the TLV value is divided by 10.

Table 9-1

HUMAN HEALTH EFFECTS OF HYDROGEN SULFIDE

H ₂ S Concentration(a) (ppmv)	Health Effects
0.00047-0.0045	Odor threshold
0.007-0.03	Slight odor
0.03	California ambient air quality standard for 1-hour average concentration based on the odor threshold
0.04-0.13	Clear definite odor
0.12	Central nervous system effects after a 1-hour average ambient exposure to this concentration
0.30	Increased incidence of nausea, insomnia, shortness of breath, and headaches after chronic exposure.
1.0-10	Incidence of decreased corneal reflex after chronic exposure
4.6	Readily apparent, offensive odor
10	Threshold limit value for 8-hour exposure at the work place
10-50	Threshold for irritative action after prolonged exposure: eye irritation such as conjunctivitis and, at the higher concentrations, dry throat. Fatigue, loss of appetite, and insomnia after chronic exposure
20-30	Very strong but not intolerable odor
70-150	Eye irritation such as conjunctivitis, keratitis, and photophobia after several hours of exposure. Threshold for olfactory paralysis occurring within minutes
200-300	Serious local irritation to eyes and respiratory tract caused upon inhalation for one hour, with possible subsequent pulmonary edema. This is the maximum concentration that can be inhaled for 1 hour without serious consequences.

Table 9-1 (Cont'd)

H ₂ S Concentration ^(a) (ppmv)	Health Effects
400-700	Threshold for acute exposure with systemic reaction and possible death from prolonged exposure. Irritative effects are severe with possible pulmonary edema. Concentration is dangerous after exposure for more than 1 hour ^(b)
700-1,500	Death occurs within 15-30 minutes of exposure ^(b)
1,800 and over	Immediate respiratory paralysis ^(b)

(a) Most concentrations cited are approximate due to the lack of precise data, the fact that most studies of H₂S are not recent, and lack of value agreement in the literature.

(b) This information is partially based on studies of dogs, which demonstrate a sensitivity to H₂S similar to that in man.

Source: Walton & Simmons, 1978

Therefore, the total adjustment factor is 42, and the EPC for the residents of the surrounding area during production is 0.24 ppmv per 8-hour period. This EPC value is a continuous value averaged over each 8-hour time period, based on the ACGIH TLV. Use of these adjustment factors results in a conservative EPC estimate. Well blowout and rupture disk situations without mitigation measures should be considered an accidental, unanticipated event. Even though H₂S reduction systems will be in place, the emissions estimates presented below assume that they are nonfunctional. It is assumed that such an event would be contained in 1 to 2 days. Therefore, the TLV value indicated above, without adjustment factors included, is the appropriate EPC value for a well blowout event. The appropriate EPC values for the various events, as well as background H₂S levels, are presented in Table 9-2.

Various states have established ambient air quality standards. California and Nevada both have significant geothermal development. The ambient standards for these two states are as follows:

California	0.03 ppmv for 1-hour averaging time
Nevada	0.24 ppmv for 8-hour averaging time

There are no federal air or emission standards for H₂S.

Background H₂S levels have been measured in the site area. Table 9-3 presents the average and maximum recorded values of H₂S measured at the Woods Station near the site during 1981-1986.

The following questions addressing public health concerns related to the project need to be answered:

- o What are the exposure levels that may result from the PGV project?
- o What is the public health risk of this exposure to H₂S?

To answer these questions, emissions criteria were calculated for the project. This information is summarized in Table 9-4 (see also Section 6, Table 6-9). Various scenarios have been considered. Normal operating conditions were addressed as well as potential emissions resulting from steam

Table 9-2

ESTIMATED PERMISSIBLE CONCENTRATION VALUES FOR H₂S

<u>Item</u>	<u>H₂S Concentration Value</u>
Background	0.001-0.048 ppmv ^(a)
Production	0.24 ppmv/8 hr
Other	
Steam stacking	10 ppmv/8 hr ^(b)
Well blowout	10 ppmv/8 hr
Rupture disk event	10 ppmv/8 hr

(a) See Table 9-4

(b) American Conference of Government Industrial Hygienist (1980)

Table 9-3

 AMBIENT H₂S CONCENTRATIONS IN THE
 PGV PROJECT VICINITY (WOODS STATION)

<u>Year</u>	<u>Ambient H₂S Concentration (ppmv)</u>	
	<u>Average</u>	<u>Maximum</u>
1981	0.0026	0.013
1982	0.0019	0.007
1983	0.0010	0.004
1984	0.0016	0.013
1985	0.0018	0.009
1986	0.0024	0.015
(through August)		

Table 9-4

ANTICIPATED H₂S PROJECT EMISSIONS

<u>Source</u>	<u>Emissions</u>	<u>Maximum Ground Level Concentration</u>
Background		0.048 ppmv
Normal operation	8 lb/hr of H ₂ S	0.008 ppmv (11.2 µg/m ³) at 1 km north of the plant
Steam stacking	430,000 lb/hr of steam at 1,300 ppm H ₂ S with 98% removal and flow rate reduced to 65% plant normal capacity	0.018 ppmv (25 µg/m ³) beyond 500 m from plant
Well blowout	150,000 lb/hr of steam at 1,300 ppmv H ₂ S with no H ₂ S removal	0.49 ppmv (680 µg/m ³) beyond 500 m from well
Rupture disk event	143,000 lb/hr of steam at 1,300 ppm H ₂ S and flow rate reduced to 65% well normal capacity	0.30 ppmv (421 µg/m ³)

stacking (venting through muffler with abatement), rupture disk event, and well blowout (well failure resulting in uncontrolled release).

The impacts of H_2S exposure at the site, as derived from these scenarios, are as follows:

- o Under normal operating conditions, the anticipated H_2S GLC from the project will be 0.008 ppmv at 1 km north of the plant. This is two orders of magnitude smaller than the EPC of 0.24 ppmv. Therefore, minimum exposure to H_2S is expected during normal operation. At 2,000 ft (600 m) southeast of the approximate distance from the plant to the nearest residence, assuming worst case weather conditions, the maximum H_2S GLC will be 0.007 ppmv ($10\mu g/m^3$). At 3.5 km, H_2S levels will have decreased to 0.0026 ppmv ($3.7\mu g/m^3$) and continue to decrease beyond that point.
- o Under the worst case scenario for a well blowout, H_2S concentrations will reach detectable limits within 500 meters of the well (point of maximum GLC) and may cause short-term eye irritation and odor problems but will not reach levels that will cause serious injury or risk to life.

Production release of H_2S at the site is significantly below ACGIH-recommended levels. Therefore, there should be minimal occupational health risk from exposure to H_2S under routine working conditions. This conclusion is supported by information generated for the Pacific Gas and Electric Company's Geysers facilities in Northern California. During a 3-year study, workers were exposed to levels of H_2S typically at concentrations of 1 ppm or less. Comprehensive physical examinations and laboratory studies were conducted at the end of each of the 3 years. No ill effects or chronic effects were observed from exposure to the H_2S or other components of geothermal emissions, such as arsenic.

Exposure to Arsenic and Its Compounds

Arsenic occurs naturally in most geothermal steam resources. Preliminary analysis of the steam condensate from Hawaii's resources reveals that concentrations of arsenic were not measured above the detection limits of the analytical methods of .01 to .5 ppm. These low levels of arsenic are below the action level as defined by OSHA, which is a concentration of inorganic

arsenic in the air of $5 \mu\text{g}/\text{m}^3$ averaged over an 8-hour period. Preliminary evidence from the PG&E Geysers project suggests there may be an exposure risk for plant maintenance workers under some maintenance conditions, such as removal of scaling from pipes, turbine blades, condensers, cooling towers, etc. Inorganic arsenic is a suspected human carcinogen and also produces a skin dermatitis. Arsenic exposure is regulated by both OSHA and the Hawaiian Department of Occupational Safety and Health (DOSH), which has established $10 \mu\text{g}/\text{m}^3$ as the PEL. Prediction of the arsenic occupational exposure is not possible with the information available and the many variables involved. The more constructive approach is to monitor the arsenic levels and take appropriate mitigation measures when necessary to protect the plant workers. If the occupational exposure exceeds $5 \mu\text{g}/\text{m}^3$, the action level, then the federal requirements of 29 CFR (Code of Federal Regulations) 1910.1018 and Hawaiian DOSH standards (Title 12, Subchapter 8) are applicable. These requirements include establishment of a medical surveillance program, personnel monitoring, change rooms, showers, and provision of personal protection equipment.

Normal Risks Associated with Working at an Industrial Facility

Construction. As with any major construction project, certain health and safety risks are associated with the operation of heavy equipment, power tools, drilling operations, noise, traffic, and hazardous material handling. Occupational hazards specific to the development of geothermal resources include the potential exposure to air contaminants, noise, heat stress, hazardous materials and wastes, drilling, and exposure to potentially hazardous contaminants found in the geothermal resources.

During the peak of construction, about 100 people will be on site, increasing the traffic load on Pohoiki Road to approximately 70 additional round trips per day.

Operation. Operation of the facility will entail health and safety risks associated with the potential exposure to high voltages of electricity, transportation to the facility, transportation of hazardous chemicals,

potential for high-pressure line rupture, and exposure to various levels of H_2S , as well as exposure to geothermal liquids and heat stress. In addition, there are certain health and safety risks associated with upset operating conditions such as free well venting or blowouts.

Experience at PG&E's Geysers project indicates that there can be an occupational skin irritation (to workers only) resulting from exposure to foams that occur around plant piping under some conditions. The skin irritation is thought to be the result of the combination of high temperature, humidity, and sulfur dust associated with the older Stretford abatement units. This type of skin irritation problem is not anticipated at the PGV Facility because Stretford abatement units will not be used and OSHA procedures will be strictly enforced.

Potential impacts from well venting and accidental releases include exposure to noise, unabated levels of H_2S , and high-temperature steam. Unplanned well venting may produce noise levels as high as 125 dBA at roughly 50 feet (Anspaugh, 1979). This level of noise is equivalent to that experienced by an observer of a jet airplane taking off at a distance of 200 feet. During a well blowout, noise levels will be similar to free well venting. The duration of noise and the uncontrolled release of H_2S and other geothermal fluids would last until the well is brought back under control. Because the olfactory threshold for H_2S can be as low as 0.00047 ppmv, the free release of significant quantities of geothermal steam over an extended period of time with H_2S concentration of 1,300 ppm could create a public annoyance. However, this is not expected under normal operating conditions.

On October 2, 1982, a free venting incident occurred at the Puna field. A valve on a well was damaged by an act of sabotage, resulting in an uncontrolled release of steam. Hydrogen sulfide emissions resulting from the free venting did not create any significant health impact. It took approximately 1.5 days before the well was capped. No injuries or serious health effects occurred as a result of this incident.

During operation, 19 employees (three shifts) will be required for the operation and maintenance of the facility, increasing the traffic load to approximately 15 round trips per day. This is an insignificant increase in traffic.

Storage and Handling of Hazardous Chemicals

The project proposes to store and use various hazardous chemicals such as NaOH in the treatment to reduce the exposure to H₂S. Transporting, storage, handling, and use of these compounds can create several potential health impacts resulting from accidental exposure. These impacts include worker exposure, which can result in severe burns or skin irritation; spills; and accidents occurring during the transportation of these compounds to the facility. Federal and state hazardous material regulations governing transportation, handling, storage, application, and use will be followed to minimize potential impacts.

9.2 PROPOSED MITIGATION MEASURES

Hydrogen Sulfide

Normal operating conditions and procedures include the collection of excess blowdown, which is injected into nonpotable aquifers, and removal from geothermal fluids of H₂S, which is also injected. This disposal procedure will greatly reduce the potential for exposure to H₂S at the facility.

H₂S is heavier than air and will displace air in confined spaces. Therefore, one must always be concerned about the presence of the gas in confined spaces. Concentrations in such spaces may reach levels much higher than the level of release from the plant during normal operations, and detection alarms and other safety devices may not be present. To avoid any potential problem or accident associated with entrance into confined spaces, all employees entering such places will be required to wear protective personal equipment until appropriate ventilation or air exchange has been accomplished. Spot test units will be available, and monitors and emergency air units will be located in strategic places. Also, work crews will include backup personnel to observe workers in risk areas. Finally, safety courses will be provided, and signs indicating high risk areas will be posted.

Exposure to Arsenic

Prior to construction and startup, a baseline monitoring program for arsenic will be established to determine the occupational exposures and to determine if the "action level" is exceeded. Monitoring of arsenic concentrations will continue during operation.

Construction and Operation

Construction and operation impacts will be mitigated through development of a Comprehensive Safety Program designed to protect the health and welfare of the workers. This program will incorporate the regulatory requirements of OSHA regulations (Title 29 of CFR, Section 1910) and the Hawaiian DOSH requirements (Title 12, Subchapter 8 of the Department of Labor and Industry), as they pertain to the construction and operation of a geothermal power facility and any other state and local health protection regulations. In addition, applicable Department of Transportation (DOT) regulations (Title 49 CFR, Sections 171-178) will be incorporated into the procedures for delivery of any hazardous materials used on site. During well drilling, monitoring for H_2S will be in place. Workers handling hazardous materials will be protected by personal protection equipment (e.g., gloves, suits, eye protection).

A landing pad for helicopters will be available at the project site for emergency use during construction and operation in case a worker is injured and needs rapid transportation to the hospital at Hilo.

During rupture disk events and blowout conditions, higher concentrations of H_2S may be present on and off site. The following mitigation measures will be placed in effect to protect worker health and safety and reduce possible releases:

- o Use of blowout preventers on all wells to automatically choke off the flow of fluids from the well
- o Minimization of free steam venting
- o Selection of optimal weather conditions for well venting

- o Use of conservative design and construction of near-surface well casing
- o Conservative design of above-ground piping systems, with automatic controls to reduce the likelihood of a rupture disc event

During normal operations noncondensable gas and cooling tower blowdown are produced; both contain H_2S . A steam release facility equipped with a rock muffler and H_2S abatement system will be used during those periods when the normal abatement system cannot be used. All produced cooling tower blowdown will be injected into deep aquifers.

Hazardous Materials

Applicable federal OSHA and DOT regulations and Hawaiian DOSH regulations will be incorporated into the procedures and standard policies of the facility. Only employees trained in the proper handling and use of hazardous materials will be allowed to work in hazardous material areas. All employees will be informed of the hazards of each compound and the appropriate emergency procedures in the event of an accidental contamination. Personal protective equipment, spill cleanup equipment, and emergency first aid stations (e.g., emergency eyewashes and showers) will be strategically located throughout the plant.

Potential problems arising from the transportation of hazardous materials will be mitigated through several measures. These measures include compliance with applicable federal OSHA and DOT regulations and Hawaiian DOSH regulations, selection of transportation routes, and scheduling transportation activities that minimize the effects on the local population.

In addition, secondary containment structures such as dikes or berms will be constructed around the NaOH storage tanks. These tanks will be segregated by distance from any incompatible material. Periodic inspection of these tanks will be performed to determine any potential problems.

The project will utilize three emergency preparedness plans; one for well drilling and testing, which has already been issued and is in effect; one for construction; and one for operation. Attached, as Table 9-5, is an outline to be used for the latter two plans. Each will be issued prior to the time they are needed. These plans will provide a comprehensive explanation of prevention and emergency response measures.

Table 9-5

PRELIMINARY EMERGENCY PLAN OUTLINE

<u>Section</u>	<u>Comments</u>
1. Introduction	Define purpose (for agencies) and scope.
2. Facility Description and Operation	Identify hazardous substances and general location. Include site plan drawing with locations identified.
3. Outside Emergency Services	Describe coordination agreements, services available.
4. Emergency Response Measures	
4.1 Onsite Emergency Responsibilities	
4.2 Onsite Equipment and Systems	
4.3 Hazard Assessment	Define emergency, selection of control measures, when to evacuate, when to notify outside services and agencies, etc.
4.4 Offsite Authority Notification	Define proper authorities to contact and notification requirements.
4.5 Control Measures	Identify general steps to be followed.
4.5.1 Chemical Spills	
4.5.2 H ₂ S Hazardous Conditions	
4.5.3 Well Blowout	
4.5.4 Equipment Failure and Pipe Rupture	Define control measures for equipment failure, such as mechanical and electrical, and pipe rupture, which includes steam, brine, noncondensable gas.
4.5.5 Fire	
4.5.6 Contaminated Soil, Water, Other Materials	
4.5.7 Other Emergencies	
4.6 Natural Hazards	Identify general response measures.
4.6.1 Lava Flow	
4.6.2 Earthquake	
4.6.3 Hurricane	
4.7 Medical Emergencies	

Table 9-5 (Cont'd)

<u>Section</u>	<u>Comments</u>
5. Evacuation Plan	Define procedures for emergency evacuation for lava flow, hurricane, etc.
6. Media Notification	
7. Personnel Training	
8. Post Emergency Reporting and Record-Keeping	Address all requirements by agencies.

Section 10
Aesthetics

Section 10

AESTHETICS

10.1 ENVIRONMENTAL SETTING

Regional Visual Setting

The aesthetic character of the region is defined by topographic features and by natural and agricultural vegetation. Because of the area's relatively high rainfall (100 to 140 in./yr), the overall impression is of lush growth, though the most recent lava flows, shown in Figure 3-1, are black and barren, contrasting dramatically with the predominant green vegetation.

The region, shown in Figure 4-1, is located on the southeastern corner of the island of Hawaii. Because the land slopes gently (generally less than 5 percent) to the Pacific Ocean in three directions, the sea may be viewed from several vantage points. To the west, the land can be seen rising to the summit of Kilauea Volcano. Along an east-west strip between Kilauea caldera and Cape Kumukahi, there is a string of volcanic craters and hills. In addition to the interesting topographic variations of these features, there is a steeper (10 to 20 percent) slope all along the rift zone.

The two most dominant volcanic hills (Pu'u) within the region shown in Figure 3-1 are Pu'u Kaliu and Pu'u Honua'ula. The latter, which is within the PGV project area, is slightly smaller and lower than the former. Both are dwarfed by the dramatic Kapoho Crater, approximately 3 miles to the east of the proposed power plant site, as shown in Figure 4-1, and the new cone from Pu'u O'o about 6 miles northwest of the site and outside the area of Figure 4-1.

The most dramatic extensive views in the region are those in which either these volcanic formations or the Pacific Ocean can be seen. Because of the rainy weather and the amount of tree cover, such extensive views are limited,

especially for travelers along the region's main highways (Kea'au-Pahoa Road/Route 130, Pahoa-Kalapana Road/Route 130, Pahoa-Kapoho Road/Route 132, Kalapana-Kapoho Coastal Road/Route 137, and Pahoa-Pohoiki Road). As one drives along these major roads, one sees an area with a clearly rural visual character.

The basic land cover types encountered are low scrub, forest, and agricultural plantings. Where the roads pass through scrub vegetation, the bushes and grasses are low, so the views are usually wide-angle or panoramic. In areas with forest cover, the view is generally restricted to the road corridor. The effect is visually pleasing, especially along the portion of Route 132 that traverses a section of the Nanawale Forest Reserve. Large canopy trees overarch the road to create a shady tunnel. Other tree-lined portions generally have more vertical species (largely ohia) that do not overarch the roadways.

The most significant agricultural crop cover is papaya. Large fields northeast and southwest of Pahoa were formerly used primarily for sugarcane. These are reverting to scrub now that the Puna Sugar Company has ceased operation.

Pahoa and the surrounding area are rural, with older structures and landscaping. Public opinion surveys (SMS Research, Inc., 1982a) indicate that local residents find agricultural technology to be familiar and, therefore, generally acceptable. Hence, they typically find even the newer, larger structures at the north end of the town to be unobtrusive because of their clearly agricultural function.

Except for Pahoa and a few scattered houses, the only major nonagricultural structure visible along the major roads is the HGP-A facility. HGP-A is located on a barren lava flow at a bend in the road where motorists have an unobstructed view of the facility. No landscaping or solid fencing screens the industrial structures and equipment. The existing well sites on the PGV land are fairly unobtrusive because of the distance from the

road, the small structures, and the lack of operational activities. Similarly, a drilling rig laid down and stored to the south of the PGV project area (at the Lanipuna No. 6 well site) is not visible from the main roads.

The view from roads and lots within subdivisions depends on the amount of development at specific locations and, in undeveloped areas, whether the natural vegetation is low scrub or forest. Generally, existing views from lots and roads within the Leilani Estates, Nanawale Estates, and Nanawale Farm-Ranch Land subdivision are limited by topography and/or the presence of natural vegetation.

Visual Setting Around the Site

The most dramatic visual features around the geothermal development site are the volcanic Pu'u and craters. Pu'u Honua'ula and the unnamed Pu'u just to the west of it are the visual focus of the project area, shown in Figure 10-1, for several reasons. First, all of the land immediately around their bases has been cleared of natural vegetation, and papayas have been planted in some areas. The contrast between the cultivated orchards and the natural vegetation on the steep sides of the conical hills makes the orchards stand out. Pu'u Honua'ula, which rises about 150 feet above the surrounding land (to an elevation of 850 feet), is the tallest volcanic feature in the immediate vicinity of the site. About 60 acres in the southwest corner of the PGV project area are covered by a 1955 lava flow. This area includes two substantial mounds of nearly barren lava (about 50 feet high) near the Pahoehoe Road.

Kahuwai Crater, Pu'ulena Crater, and Pawai Crater, located about 1 mile southwest of Pu'u Honua'ula, are impressive depressions several hundred feet deep, but these features are not visible except from the craters' edges. While the topography rises slightly to the rims of the craters, their forms are largely masked by the heavy vegetation around them.

Within the PGV project area there is one major stand of trees, and much forested land is nearby (see Figures 3-3 and 7-1). Approximately 1 mile northeast of the proposed power plant site is Lava Tree State Park, which is

both an aesthetic and geological resource of the area. Lava molds of trees stand among ohia trees and fern growth, forming an attractive and interesting environment. The north sides of Pu'u Honua'ula and neighboring Pu'u are visible from the southeastern corner of the park. However, the mass of these cinder cones lies between the park and the power plant site. A more detailed discussion of the vegetation around the proposed plant site is provided in Section 7.

10.2 ENVIRONMENTAL IMPACTS OF THE PROPOSED ACTION

Geothermal facilities have already been developed on and near the PGV project area, as shown in Figure 3-2. A plan view of PGV's proposed geothermal facilities is shown in Figure 2-2. The visible construction activities of the proposed PGV project, as well as the industrial structures and facilities themselves, will tend to be an intrusive element in a largely rural scene. Attention of travelers through the area may focus on these visual changes, which include removal of vegetation, change of landform by grading, installation of new structures, and occasional steam plumes from testing wells.

During the initial construction phase, grading for the power plant will start. A new production wellpad and the injection wellpad will also be installed during this initial phase. It is currently anticipated that during the life of the plant two additional wellpads will be constructed, as needed.

An obvious visual change will occur when small rectangular areas of land and the corridors between them for the steam pipes are cleared of green vegetation, exposing the dark basalt and soil underneath. Of a total of 12 acres required for the project, 2 acres do not need to be cleared because they are located on barren, black lava flow; 7 acres have already been cleared; and 3 acres of inactive papaya orchard remain to be cleared.

Large areas in the region are periodically cleared for agricultural operations, and the clearings required for this project are much smaller than typical agricultural plots, being more comparable to house lot clearings in the surrounding subdivisions. The most substantial grading will be for the



MAP LOCATION

HAWAII HILO

LEGEND:

- POWER PLANT
- PRODUCTION WELLPAD
- LIQUID INJECTION WELLPAD
- TEMPORARY CONSTRUCTION YARD
- ▲ OBSERVATION POINT

SCALE

CONTOUR INTERVAL 20 FEET

0 1 MILE

0 2000 4000 FEET

0 1 KILOMETER

SOURCE: U.S.G.S., 1980, 1981a, 1981b

**PUNA
GEOTHERMAL VENTURE PROJECT
HONOLULU, HAWAII**

**Figure 10-1
TOPOGRAPHIC MAP
OF THE GEOTHERMAL FACILITIES
AND SURROUNDING AREA**

BECHTEL GROUP, INC.	JOB NO. 15722	DRAWING NO.	REV.
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power plant pad and wellpads. The cut-and-fill slopes there will appear angular and engineered, contrasting in color and shape with the surrounding, smoothly contoured, vegetated slopes. Approximately 2 of the 12 acres have already been graded, leaving about 10 more to be graded.

Fences will be erected around all wellpads and the power plant pad. Concrete and metal structures will tend to be visible because of their contrast in color, form, height, and texture with their surroundings.

The tallest piece of construction equipment will be a large drill rig, which is about 150 feet high. This rig will be used for drilling production and liquid injection wells. It takes approximately 60 days to drill each of these wells. A smaller rig, about 30 feet high, will be used for the shallower gas injection and monitoring wells. Initially, four new deep wells are needed; hence, the large rig will be on the PGV project area for approximately 8 months. The large rig will return the following year for about 6 months to drill the three additional deep wells.

Periodically, the rig will return to the site to drill makeup wells and for remedial or maintenance work. High-level lighting will be required at night during drilling for this round-the-clock operation. Shielding requirements and intensity levels are set by county and state regulations and permit conditions.

Most of the major structural installations will be at the power plant site on the south side of Pu'u Honua'ula. The plan and elevations drawings of these facilities are presented in Section 2.4. The expected dimensions, construction materials, and color are listed in Table 10-1. Design decisions, however, have not been finalized. None of these structures will project above the Pu'u Honua'ula skyline when seen from adjacent properties.

Production wellpads will be designed to accommodate up to four wells per wellpad. The injection wellpad will be designed to accommodate up to three injection wells. Initially, each wellpad will have one or two wells. All of these new structures and equipment will be most visible during the initial construction period, before landscaping is installed.

Table 10-1

VISUAL FEATURES OF POWER PLANT FACILITIES

Facility	Dimension (ft)		Outer Material	Available Colors
	Plan View	Height		
Turbine building	143 x 73	32.5	Corrugated aluminum siding	Not fixed
Cooling tower				
Basin	150 x 52	5	Reinforced concrete	Gray
Main section	150 x 73	30 to 50	Fiberglass-reinforced plastic	Gray, beige, light green
Stacks	314 sq ft circles	8 to 15 addit.	Fiberglass-reinforced plastic	Gray, beige
H ₂ S abatement system	80 x 85	-	Various metals	-
Switchyard	122 x 122	-	Steel structures and wires	Gray/silver
Transformers	10 x 8	-	Steel	-
Silica scrubbers	33 sq ft circles	15	Carbon steel	-
Wellheads				
Particle separators	9 x 2	2	Carbon steel	-
Moisture separators	1 sq ft circle	17	Carbon steel	-
Condensate storage	154 sq ft circle	-	Stainless steel	Silver
Rock muffler	10 x 16	16	Reinforced concrete	Gray
NaOH storage tank	616 sq ft circle	8.4	Concrete dike	Gray
Fencing	-	7	Chain link topped w/barbwire	Gray, green

Construction of the geothermal facilities will also involve installation of a gathering and injection system. The major pipelines, between the wellpads and the power plant, range in diameter from 18 to 24 inches. These steam collection pipes run above ground and are usually raised no more than 5 feet above the ground, except where they cross roadways. At such crossings they may be routed in a door-frame shape as high as 17 feet. These pipes will be constructed of carbon steel and covered with aluminum, which will be painted to blend into the surroundings.

Until operation of the power plant starts, small plumes will be produced occasionally by the wells during short testing periods. The visibility of a plume will depend on weather conditions and viewing position. Viewed from below against a cloudy sky, it will not be very noticeable. Viewed from a high vantage point against vegetation or earth, or viewed against blue sky, it will be more apparent. However, the tradewinds are fairly constant and will disperse the plumes.

The last stage of construction at each of the wellpads or the power plant pad will be the installation of landscaping. State regulation (Hawaii State Department of Land and Natural Resources, 1981, Section 13-183-87d) requires the following of geothermal facilities: "Facilities will blend into the natural environmental setting of the area by the appropriate use of landscaping, vegetation, compatible color schemes, and minimum profiles. Native plants or other compatible vegetation shall be used, where possible, for landscaping."

Three categories of construction activity viewing points were assessed:

- o The public road network in the area of the site (the project's visibility from any section of it will affect many travelers)
- o Residences and potential home sites on lots in the area (the number affected may be very small, but the impact could be long term)
- o Public places, which are sensitive to changes in their views

Figure 10-1 is a topographic map of the proposed geothermal facilities site and its surrounding area. Eight numbered locations are shown on this map. Figures 10-2 through 10-9 show what a standing observer, looking towards the geothermal site, will see from each of these locations.

The views from the two highways bordering the PGV-leased land were studied first. Most of the western boundary of this leased land along the Pahoa-Pohoiki Road is lined with hedges. These are generally high enough to confine views to the east from most passenger cars, except where a few breaks in the vegetation allow glimpses of Pu'u Honua'ula and neighboring pu'u. Travelers in buses and trucks may be able to see continuously the two pu'u over the hedges. However, along this same stretch there is little or no view of the power plant site because of the vegetation and the pu'u west of the site. Figure 10-2 shows the line of sight of an observer standing at location 1 (see Figure 10-1) and looking towards the plant. A hedge with an average height of 10 feet obstructs the observer's view at this location. Travelers in buses and trucks will be able to see the entire cooling tower as they pass this point.

Because of its height, the drilling rig will probably be visible from the nearby roads wherever the vegetation does not totally confine views to the roadway corridor. Just to the north and south of the project site, there are thicker stands of tall canopy trees that effectively block views to the east.

Further south, towards the HGP-A site, the stands of trees thin out, but some landscaping has been done around the HGP-A visitor center. It is possible to catch a glimpse of the power plant site beyond the HGP-A complex, but the HGP-A facilities adjacent to the road will be more dominant than those on the hillside 1/2 mile away. From HGP-A south to where the road turns eastward, there are breaks in the stands of ohia trees and the roadside embankment from which views of the pad locations are possible. Moreover, as houses are built on these already subdivided lots, trees may be removed. After the road turns eastward, there is an almost unbroken line of trees along the road where glimpses of the proposed PGV facilities (at a distance of about 4,000 feet) are possible between the tree trunks. After the road bends to the

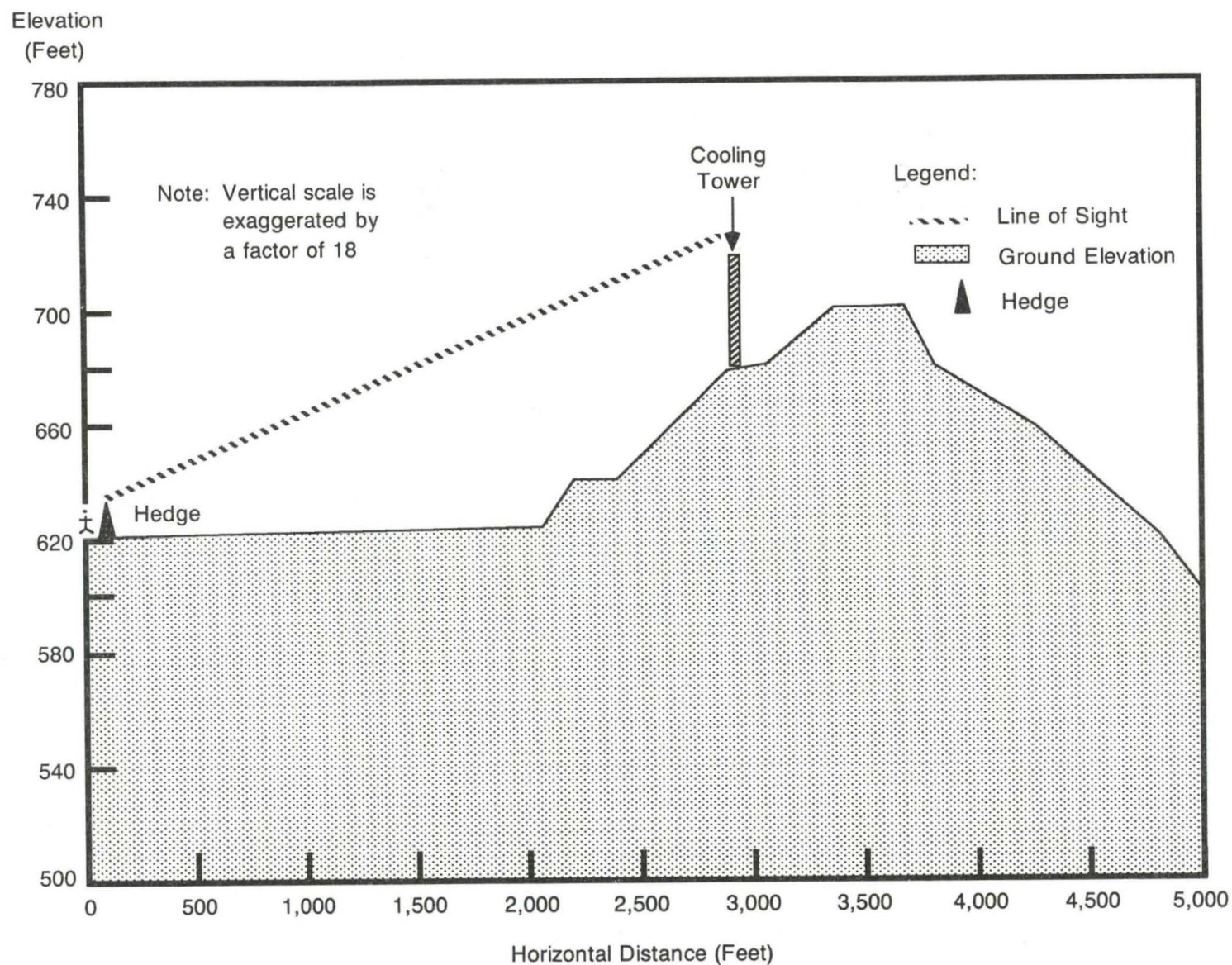


Figure 10-2 OBSERVER'S LINE OF SIGHT FROM LOCATION 1 ON PAHOA-POHOIKI ROAD

south again, the facilities on the PGV site will no longer be visible from this highway because of the woodland on each side of the road.

Along the Highway 132 boundary of the PGV project area, there is very little vegetation that blocks views to the south. Hence, construction activities on the wellpads will be visible from the highway. However, once installed the facilities at the wellpads will not be very noticeable. Assuming landscaping on the outside of the fences around the pads, the only pieces of equipment that will project above the fences are moisture separators, which are 17 feet tall but only 30 inches in diameter. Because all the wellpads are at least 2,000 feet from Highway 132, the separators will be barely visible. For the most part, the structures and construction activities at the power plant site will be hidden from the view of travelers along Highway 132 by Pu'u Honua'ula. When wells are being drilled at Wellpads C and D, the drilling rig will be visible.

Figure 10-3 shows the line of sight of an observer standing at location 2 on Highway 132 (see Figure 10-1) and looking between Pu'u Honua'ula and its neighboring pu'u, towards the geothermal site. This observer will see the upper third of the power plant cooling tower. A new road will be built from Highway 132 at location 2 to the geothermal facility. A temporary 5-acre construction yard will be provided next to this new road and will be visible from location 2.

Location 3 is also on Highway 132, east of location 2. From this point, Pu'u Honua'ula blocks the view of the geothermal site. Figure 10-4 shows the line of sight of an observer standing at location 3. Wellpads C and D will be visible from this location.

Views of the PGV site from roads in the Leilani Estates subdivision are now blocked by forest. Location 4 is at the highest elevation on Kahukai Street. From this location, an observer's view of the plant site is blocked by trees. Figure 10-5 shows the positions of the observer, trees, and cooling tower. Location 5 is another high point in Leilani Estates. Trees obstruct an observer's view of the plant from this location. The positions of the observer, trees, and cooling tower are shown in Figure 10-6.

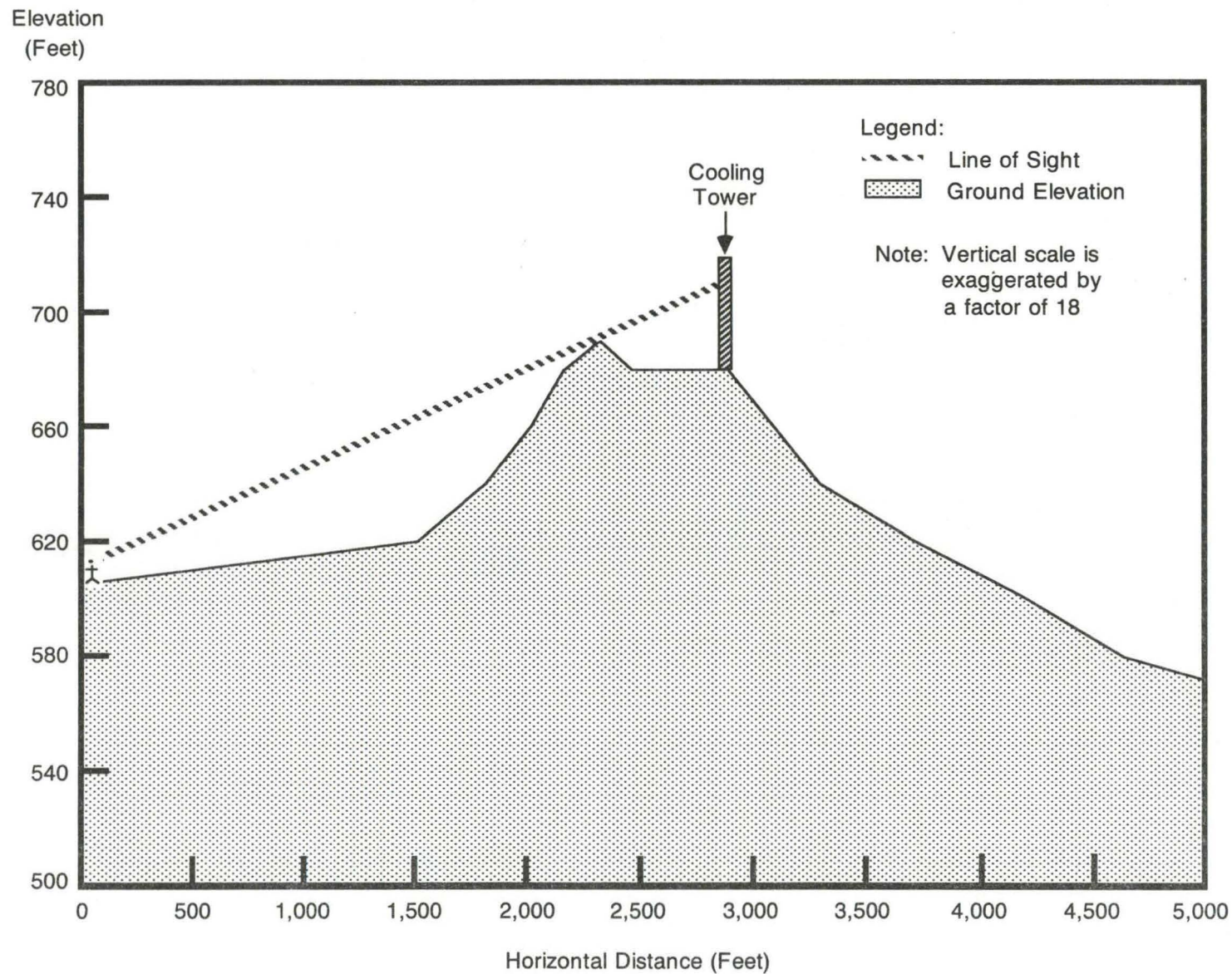


Figure 10-3 OBSERVER'S LINE OF SIGHT FROM LOCATION 2 ON HIGHWAY 132

10-14

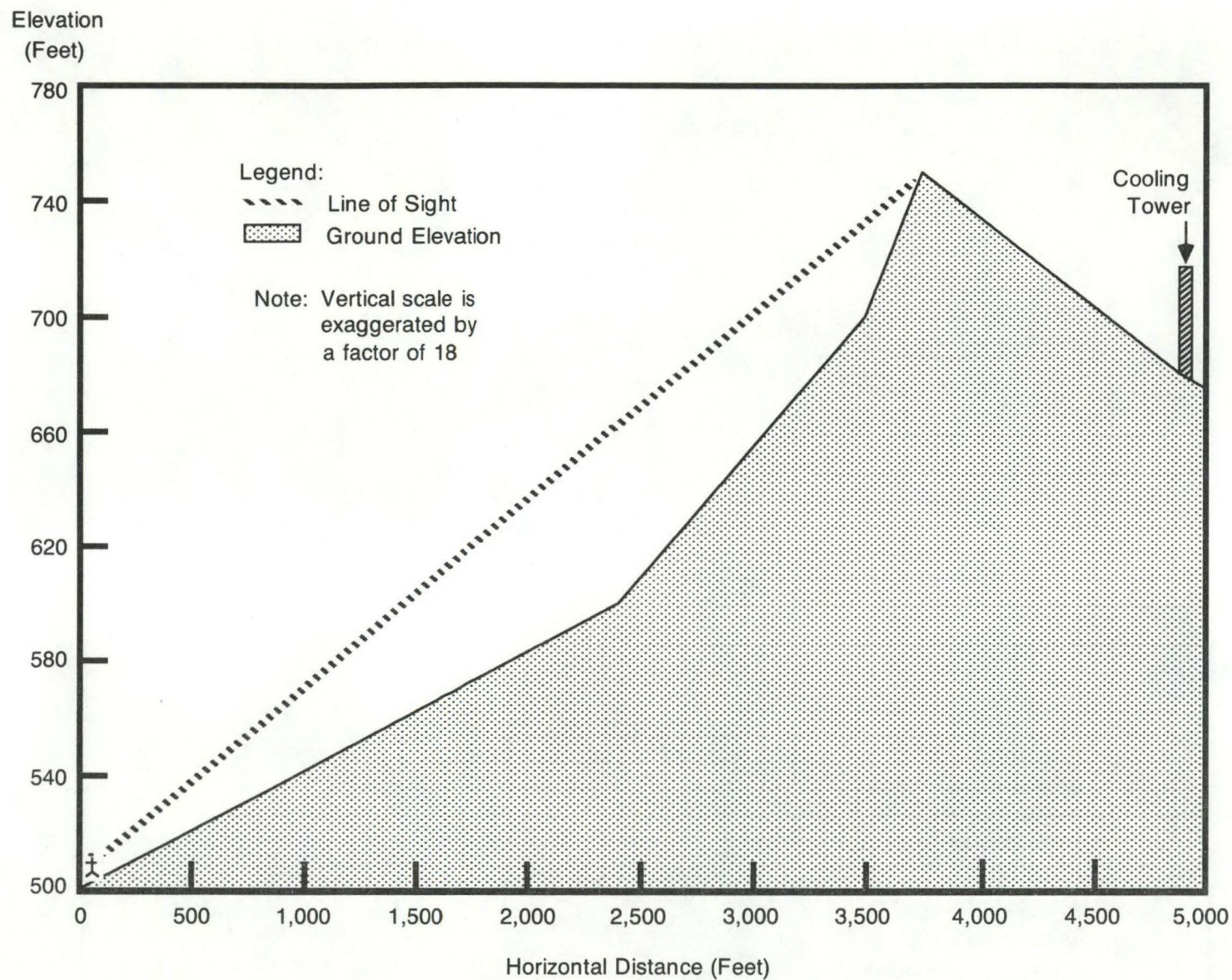


Figure 10-4 OBSERVER'S LINE OF SIGHT FROM LOCATION 3 ON HIGHWAY 132

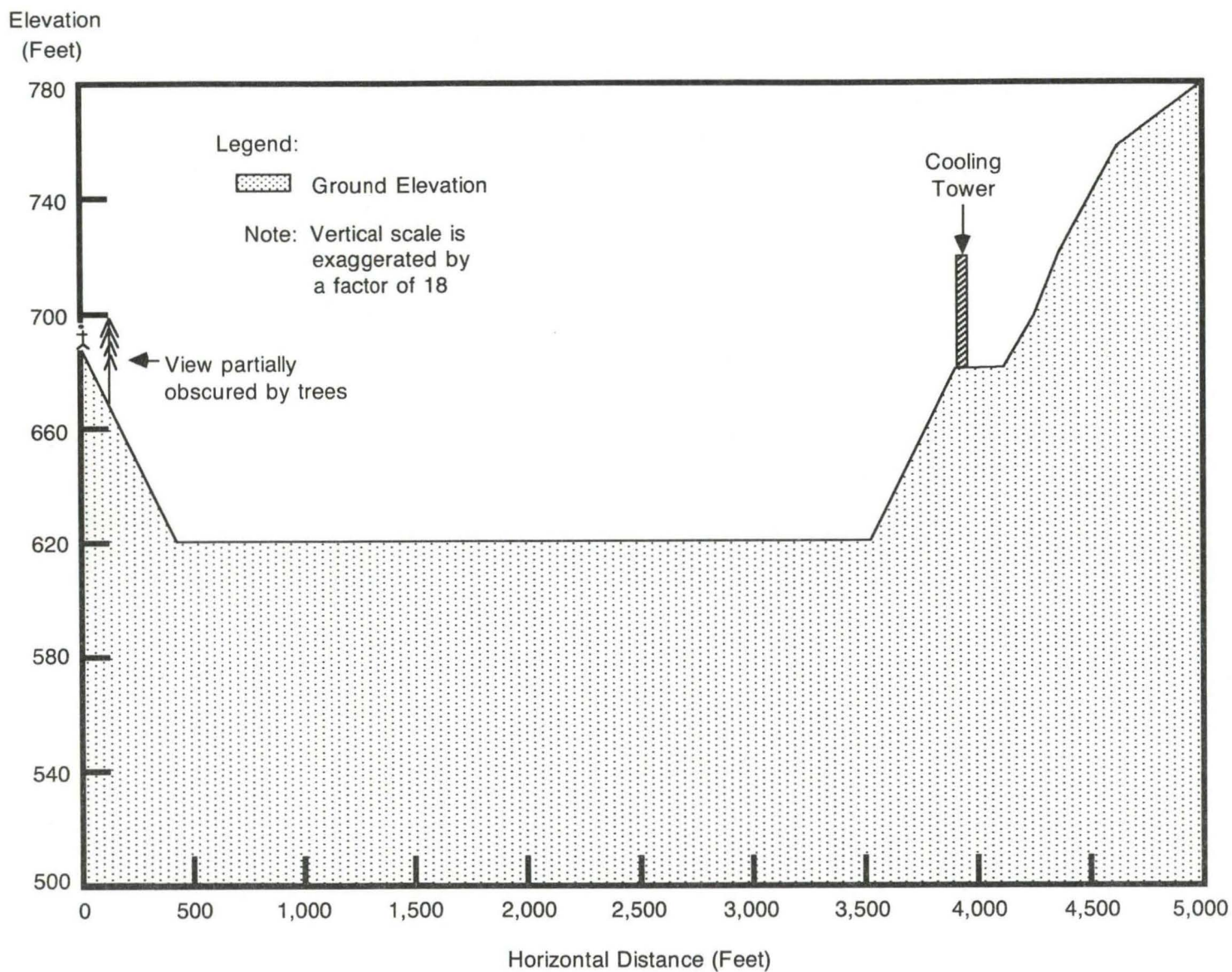


Figure 10-5 OBSERVER'S LINE OF SIGHT FROM LOCATION 4 ON KAHUKAI STREET

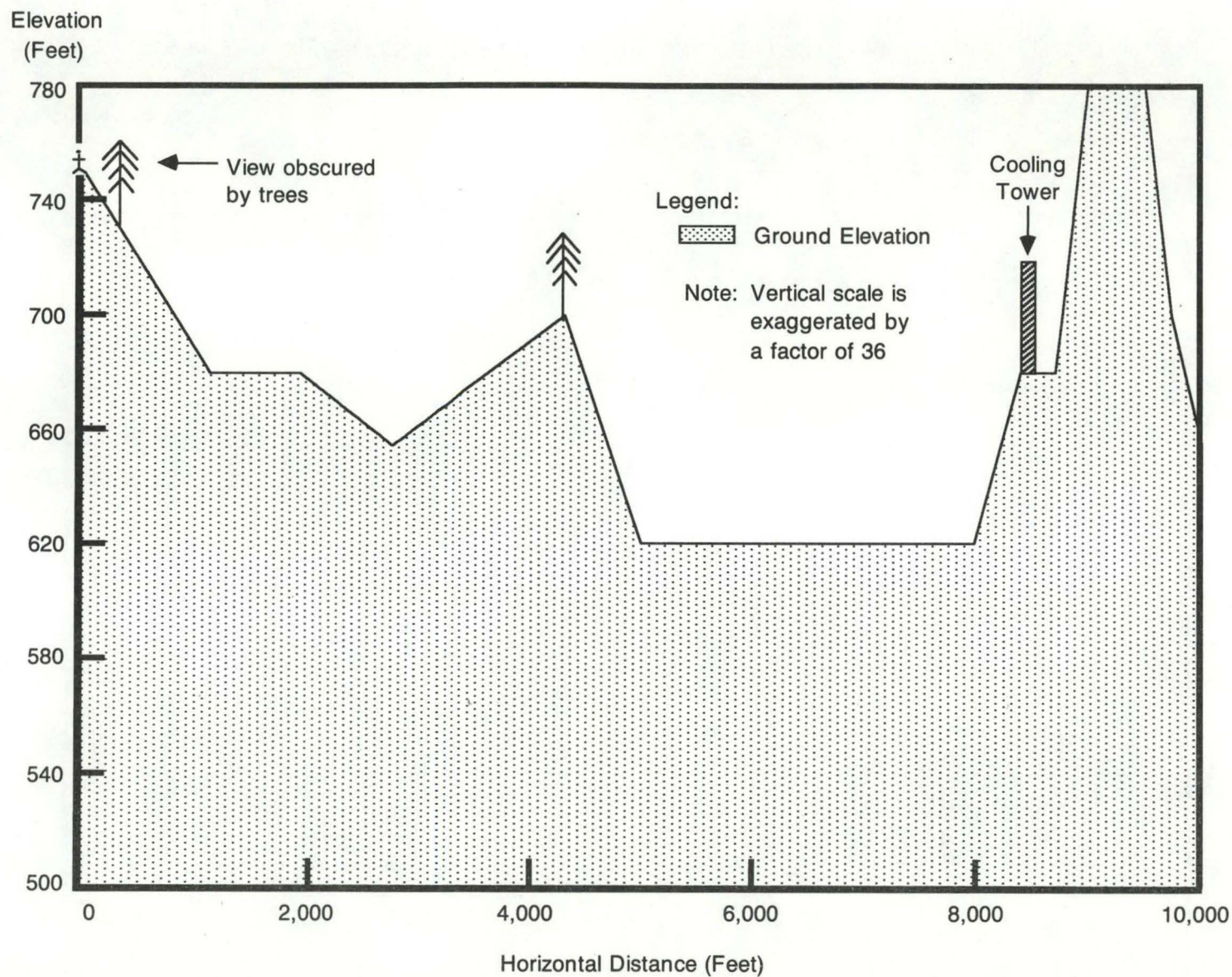


Figure 10-6 OBSERVER'S LINE OF SIGHT FROM LOCATION 5 IN LEILANI ESTATES

If a large number of the lots at the eastern end of the subdivision are cleared and developed, the PGV site may become visible. However, with tens of thousands of undeveloped lots in the Puna District and the present slow rate of development (fewer than 200 lots in the 2,266-lot Leilani Estates subdivision have been developed for residential use since 1960, when the subdivision received final plan approval), it is unlikely that views of the PGV site will open up before construction of the major facilities is completed and landscaping is installed. Long-term visual impacts on both subdivision roads and future residences are discussed later in this section.

Since it is a through street between the Pahoa-Pohoiki Road and Highway 130, Leilani Avenue carries traffic beyond the requirements of the subdivision resident population. From Leilani Avenue at Mohala Street, Pu'u Honua'ula lies directly in the view of east-bound travelers for approximately 3,000 feet, though there is a dip from which the view is blocked. At the usual speeds, the view of the power plant pad will be very brief. The scenery is not totally rural and natural; presently, travelers see the cut in Pu'u Honua'ula for the Wellpad B and the roof and steam plume from the HGP-A facility. Construction equipment and activities on the power plant pad will make the scene for travelers on this road somewhat more industrial during PGV project construction. Once landscape is established around the fences, the view may be considerably improved, as the excavation cut on Pu'u Honua'ula will be hidden. Figure 10-7 shows that, from location 6 on Leilani Avenue, an observer's view of the plant site is partially obscured by trees. Figure 10-8 shows a photomontage of the view from the crest of Leilani Avenue, before landscaping is put in.

Two short segments of Hinalo Street, which traverses a lava flow with only a short grass cover, have wide-angle views that include most of the wellpads and power plant pad. Construction activities such as clearing and grading and erection of structures and equipment will be visible for a few seconds at 25 mph. Currently, only a few subdivision residents use this dead-end street. Landscaping will be installed around the pads before this subdivision road is more heavily traveled. Location 7 is on Hinalo Street in the area described above. Figure 10-9 shows that an observer standing at this location will get a clear view of the geothermal site and the top 30 feet of the power

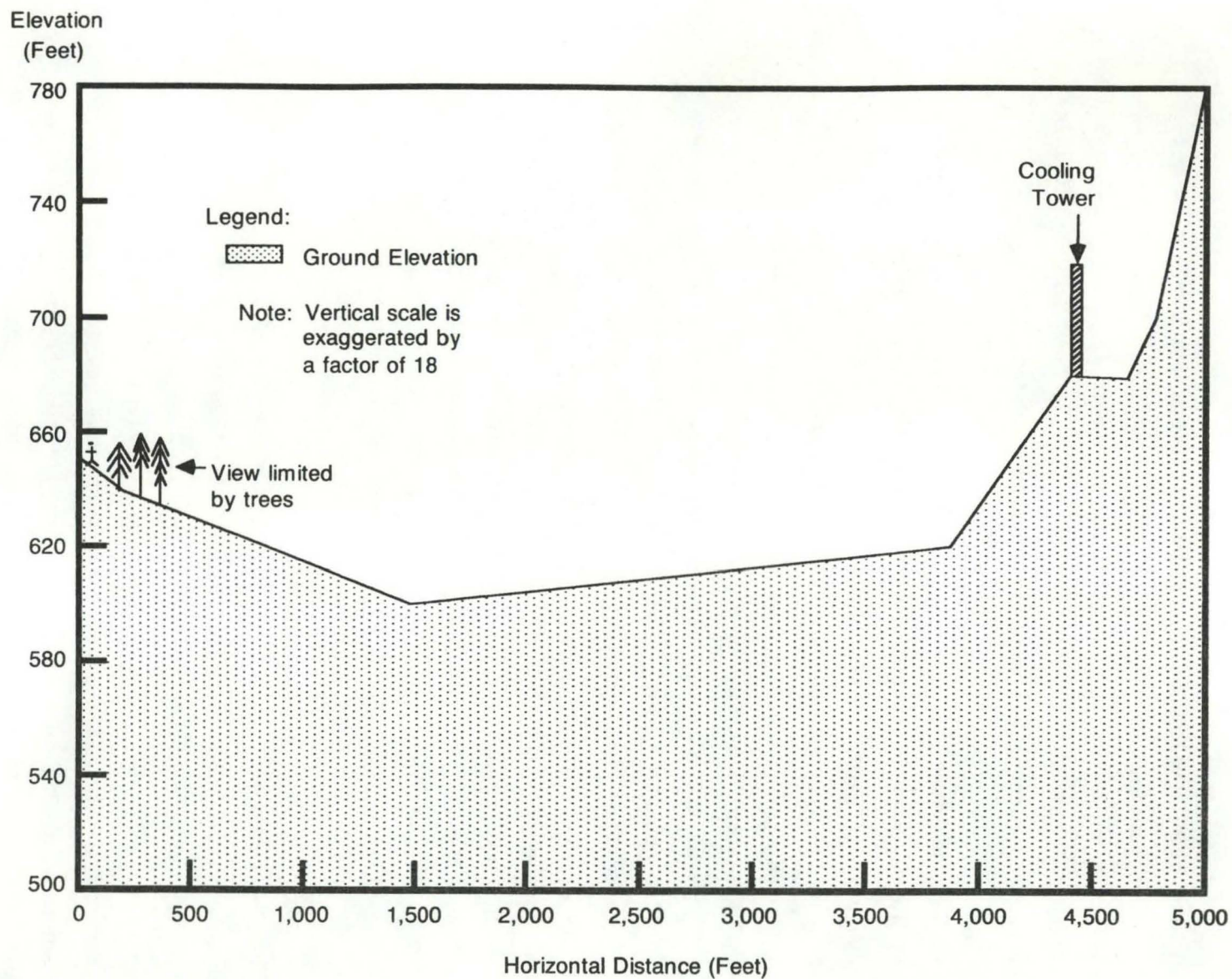


Figure 10-7 OBSERVER'S LINE OF SIGHT FROM LOCATION 6 ON LEILANI AVENUE



Figure 10-8 PHOTOMONTAGE OF PROPOSED PGV FACILITIES VIEW FROM LEILANI AVENUE

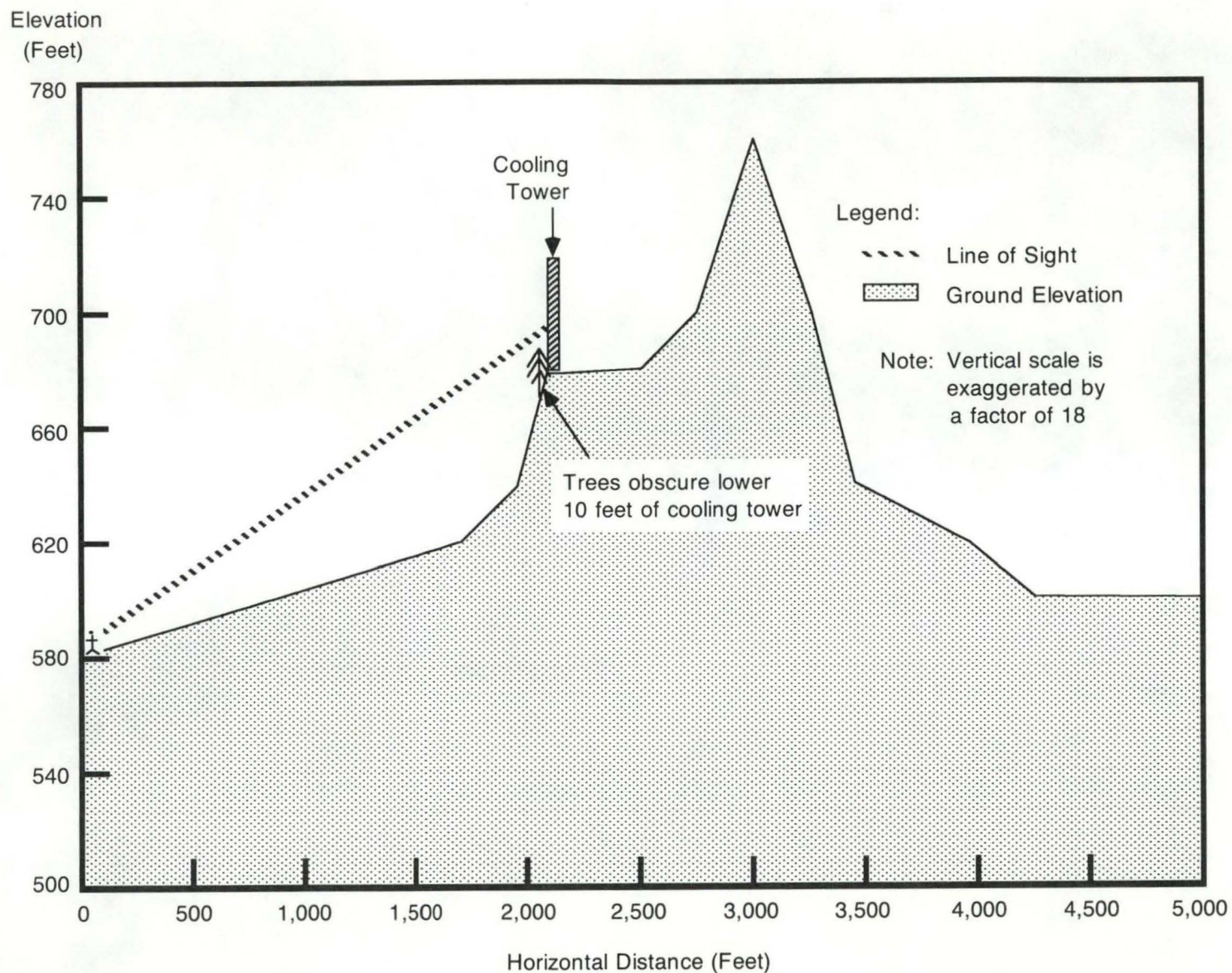


Figure 10-9 OBSERVER'S LINE OF SIGHT FROM LOCATION 7 NEAR PAHOA-POHOIKI ROAD

plant cooling tower. The turbine building is completely blocked from view by the cooling tower.

Currently, a few residences may have views of the proposed sites for the well and power plant pads. Those closest to the site include one house about 1,000 feet southeast of the injection wellpad, which has a view of the plant site from the rear of the house. Vegetation and topography will shield views of the project from other houses in the vicinity. Papaya farmers will be able to see the construction activities clearly whenever they are working in the orchards to the south of Pu'u Honua'ula.

Almost all of the undeveloped lots are densely forested so that a vegetation screen can be left when they are developed. About four lots bordering the PGV project area in the Lanipuna Gardens subdivision are on a recent lava flow. These lots are about 2,000 feet from the base of Pu'u Honua'ula and have an expansive view of the PGV site. Given the supply of lots and their development rate in Puna, development of these lots is not likely until after the geothermal facilities are constructed and landscaped.

Because maintenance of their scenic quality is critical, any potential impacts the project may have on the views from public places, especially parks, were also assessed. From the shoreline areas, about 3.5 miles away, Pu'u Honua'ula is visible where there is no high vegetation in the near foreground. However, at that distance, construction activities will not be very noticeable, except for the lights used during well drilling. These will be visible because of the height of the drilling rig and the night lighting needed for drilling. Location 8 is along Route 137 between Kapoho Crater and Pohoiki, near the ocean. Although an observer can see the entire cooling tower from location 8, as shown in Figure 10-10, the visual impact is greatly reduced by the distance. Because of the Malama-ki Forest Reserve to the north, Mackenzie State Park on the southern Puna coast has no view of the PGV project area.

The other nearby public park of concern is the Lava Tree State Park. The north side of Pu'u Honua'ula and neighboring Pu'u will block views of the

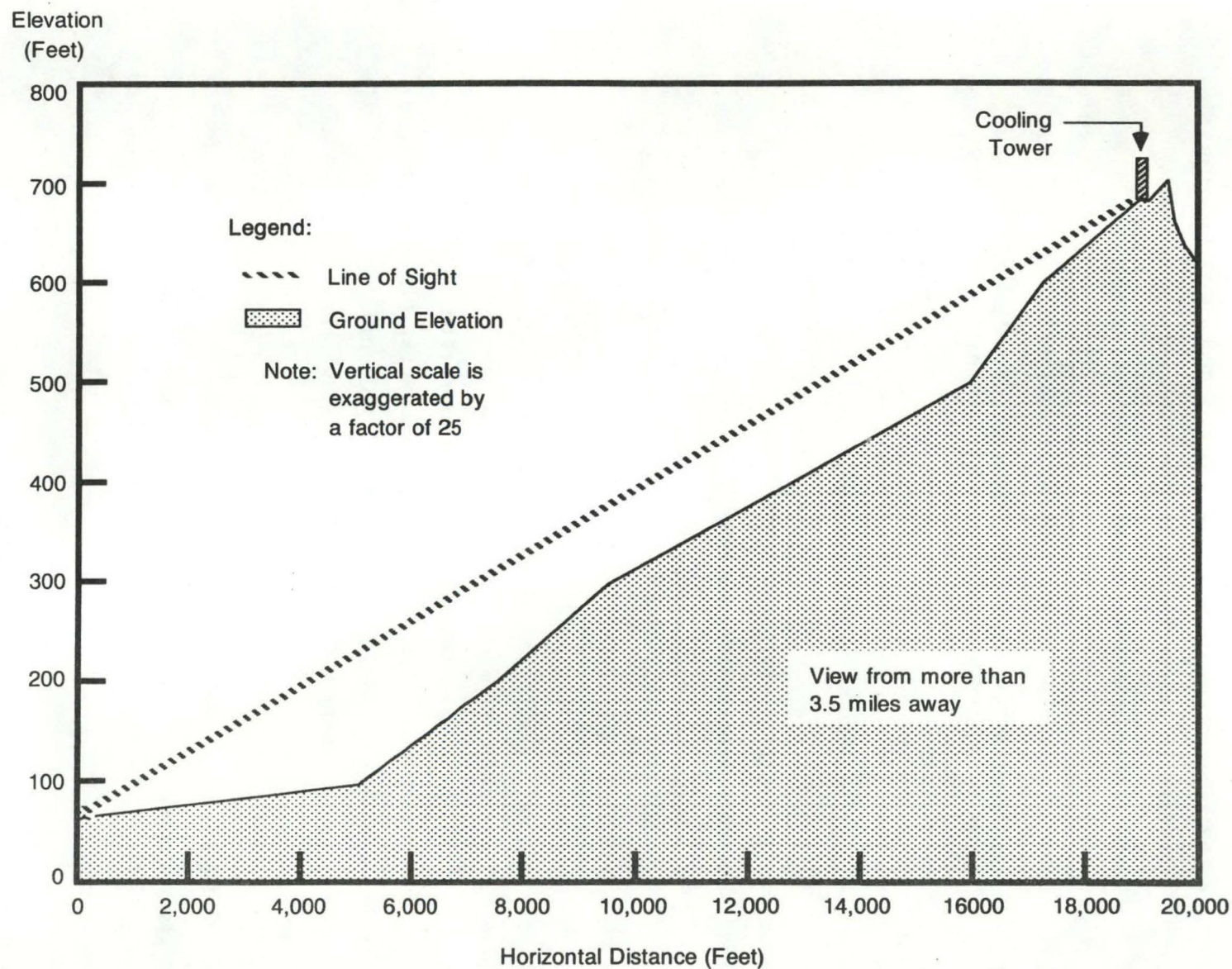


Figure 10-10 OBSERVER'S LINE OF SIGHT FROM LOCATION 8 ON HIGHWAY 137

structures on the power plant site. However, the drilling rigs on Wellpads A, C, and D may be visible to park visitors if they walk off the trail to the western boundary of the park, which borders land with only sparsely scattered trees.

Because one's overall opinion of a project affects one's assessment of its visual impacts, an evaluation of the significance of visual changes resulting from project construction is necessarily subjective. The public should be informed that landscaping will be installed around the pads once construction is completed; therefore, cleared and graded areas during construction will not be permanent scars, but necessary steps in the development process.

It is the level of activity on the site, especially marked by movement of equipment, as much as the industrial structures and equipment that will seem unusual for the area because it will alter the rural ambience. In the final stage of construction, the pads will be landscaped to screen the structures from view.

The only locations from which the PGV facilities will be a significant visual element are the eastern 3,000 feet of Leilani Avenue and the four house lots in the Lanipuna subdivision. Even at these locations, for travelers along the Pahoa-Pohoiki Road the facilities will be far less dominant than the HGP-A plant. Despite the limited scale relative to the overall scene, the location on a hill, the contrast with surrounding vegetation, and, most importantly, the fact that the structures are situated in a community where geothermal development has been controversial, the geothermal facilities will attract more attention during construction than larger scale agricultural clearing or subdivisions.

Once construction is completed, landscaping will be installed around the perimeter of the wellpad and power plant fencing. With less construction activity, the site will be less noticeable, and once landscaping matures, most of the structures will be hidden. However, steam plumes produced by operation of the proposed facility may be a visible indication of the facility's presence. Under normal operating conditions, the only steam plume will be from the cooling tower. The visibility of the cooling tower plume depends

upon the ambient weather conditions. The plume is not expected to be visible on warm days with average humidity; however, visibility increases as the ambient temperature declines and humidity increases. Therefore, a visible plume is expected on cold days with moderate to high humidity.

On occasions when it is necessary to divert geothermal steam from the power plant, there will be a somewhat more dense plume from the rock muffler. Normally, no plumes will be visible from the wells.

From the south of the project site, a white plume may be visible because of its contrast with the dark vegetation on Pu'u Honua'ula. Weather conditions will determine whether the plume will be visible from the north as it rises above Pu'u Honua'ula. Against a cloudy sky it will not be very noticeable; against a blue sky it will be quite noticeable. On a calm day the plume will rise straighter and higher than on the normally windy days in Puna. Under the more usual weather conditions (rainy and breezy) in Puna, the range of visibility will be much reduced.

As discussed in Section 2, the geothermal facility site will be restored to its original condition when the project is abandoned. The removal of all equipment and structures and the revegetation of the land will generally return the area to its original appearance. As the geothermal facilities are being dismantled, the level of activity visible on the site will be higher than during the normal operation period. The most visible evidence of the activity will be the truck traffic to and on the PGV-leased land, since the established landscaping around the well and power plant pads will screen views of the dismantling activities there.

10.3 PROPOSED MITIGATION MEASURES

To minimize the visual scars created by clearing and grading activities, the cut-and-fill slopes will be engineered to look rounded, so that the transition to the surrounding terrain looks more natural. Graded areas will be landscaped promptly to avoid bare, vertical cuts such as the one behind Wellpad R.

Landscaping will be planted around the well and power plant pads, and the pipelines between pads will be painted to blend in with the surrounding natural colors. For compatibility, the use of native plants for landscaping is preferred.

The mitigation of the visual impacts of night lighting during drilling will be specified, in terms of shielding requirements and lighting level limits, as conditions in the various state and county permits required for the project.

About four lots in the Lanipuna Gardens subdivision have wide-angle views to the north of the existing and proposed pads, which include some industrial structures. These views can be blocked by planting a boundary of trees and shrubs along the PGV-leased land bordering these lots. Landscaping around the pads, once matured, should obscure most of the existing and future industrial buildings and equipment without blocking the wide-angle view that encompasses the visually dramatic Pu'u Honua'ula. Lot owners may prefer a vegetation screen at the pads (though it may not be as effective immediately) to a line of vegetation adjacent to their lots that entirely obstructs their view in that direction.

As previously discussed, landscaping will be installed around the power plant and wellpads to screen the industrial structures and equipment. The choice of plant material will take into account which species are tall enough to screen the tallest structures at each pad and which species are hardy enough to thrive under the site's environmental conditions.

Because it may take a few years before plants and trees grow tall enough to screen the structures, the colors of all structural materials will be selected to blend in with surrounding vegetation. Dark greens or grays are the best colors to use, depending on background vegetation. Reflective metal surfaces will be coated or screened with solid fencing.

The layout of the wellpads has been designed to minimize the amount of land that must be cleared for additional roads. Lining the roads and the

pipeline routes with vegetation is an additional mitigation measure under consideration.

In choosing the location of the power plant and wellpads, the original siting study (Bechtel National, Inc., 1984) took visual concerns into account. The landscaping, plant screens, and siting choices will effectively screen the geothermal facilities and structures, but the plumes of steam from the cooling towers and rock muffler cannot be hidden. Steam plumes tend to be less visible at the warm, daytime temperatures prevalent at Puna.

No visual impacts from facility decommissioning are expected, except for the slightly increased activity necessary to return the land to a natural appearance. The landscaping installed for the project and for revegetation of the pads will improve the original scenic quality.

Section 11
Socioeconomics

Section 11

SOCIOECONOMICS

11.1 ENVIRONMENTAL SETTING

Population Characteristics

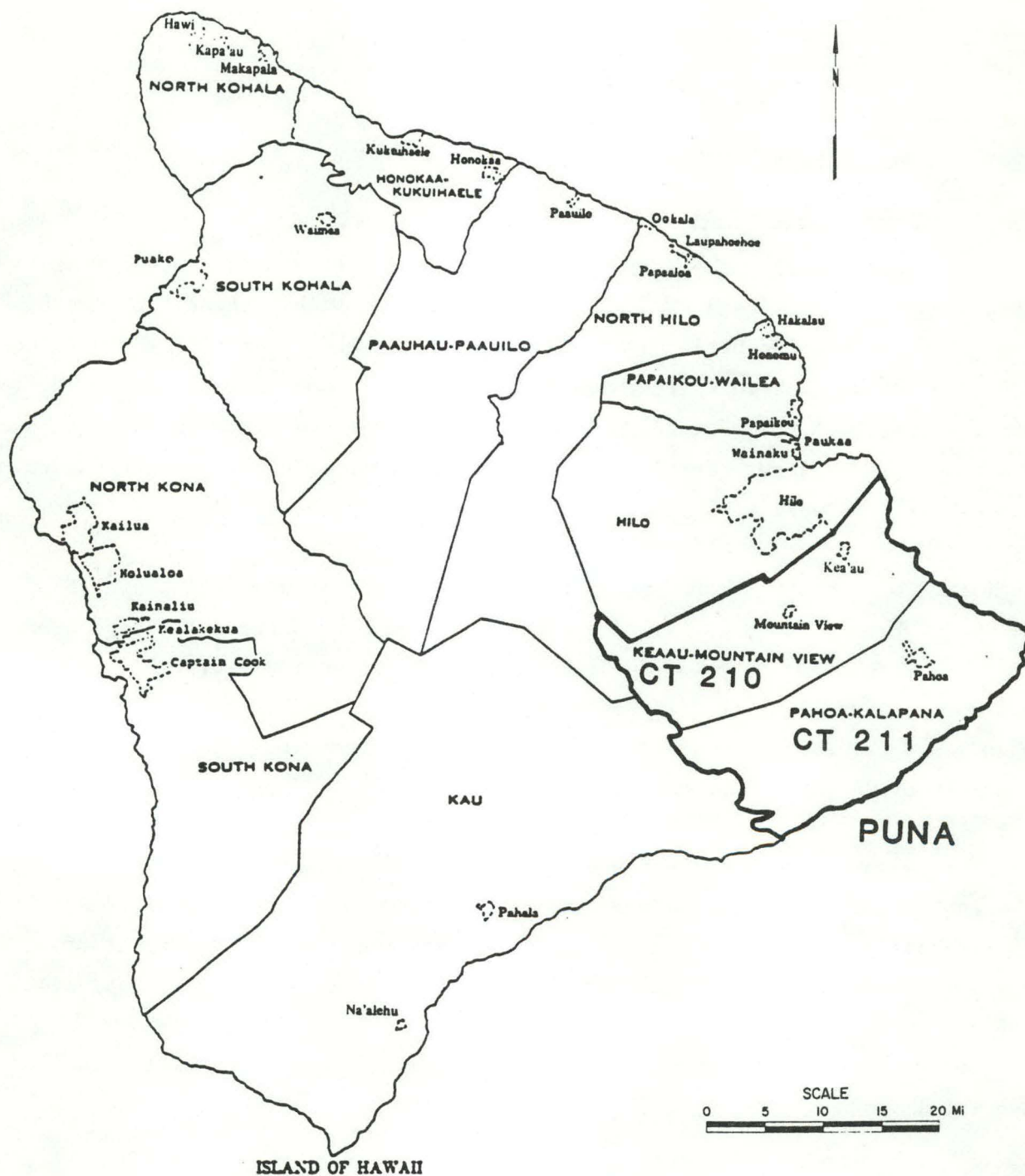
The Puna District comprises two census tracts: CT 210 (Kea'au-Mountain View census division) and CT 211 (Pahoa-Kalapana). Within these two tracts, published census information is also available for three Census Defined Places (CDPs): Kea'au, Mountain View, and Pahoa. Pahoa is the closest settlement to the PGV project site. Figure 11-1 shows the location of the Puna District and its three CDPs. Figure 3-1 in Section 3 shows the project site location and nearby subdivisions.

Regional Population. According to the 1980 census, the population of the island of Hawaii was slightly in excess of 92,000 - a 45 percent increase over the 1970 population of 63,500. This compares to an increase of only 3.5 percent from 1960 to 1970 and a 10.3 percent decrease from 1950 to 1960, when many residents left the island to find better economic opportunities in Honolulu or on the mainland.

The island land mass comprises 2,583,680 acres, about twice the size of the rest of the Hawaiian Islands combined, and a population density of about 20 persons/mi², the lowest of all Hawaii's counties. About 40 percent of the island's current population is concentrated around Hilo, the county seat.

During the 1970s, Hawaii Island's demographic composition shifted in several important ways:

- o The proportion of population under age 18 dropped from 36 percent in 1970 to 31 percent in 1980.
- o The average education level increased.



SOURCE: State of Hawaii, Department of Planning and Economic Development, STATISTICAL BOUNDARIES A-15. 1980:14.

Figure 11-1 LOCATION OF THE PUNA DISTRICT, CENSUS TRACTS, AND CENSUS DEFINED PLACES

- o In-migration increased so that by 1980 one out of every four residents had not lived on the island 5 years previously (44 percent of the net population growth from 1970 to 1980 consisted of persons born outside the state of Hawaii).

The largest demographic change during the 1970s was the proportionate decline in Japanese residents and increase in (primarily) Caucasians and (secondarily) native Hawaiians. As of 1980, more than half of the island's population fell into one of the latter two ethnic groups (Table 11-1), and nearly eight out of every ten net additional residents from 1970 to 1980 were either Caucasian or Hawaiian (Table 11-2). Some of the apparent statewide increase in native Hawaiian population may have been due to changed U.S. census recording procedures for persons of mixed ancestry and/or to the 1970s Hawaiian cultural renaissance, which is believed to have resulted in more part-Hawaiian people choosing to label themselves Hawaiian in 1980 than in 1970.

Population increase from 1970 to 1980 was particularly marked in the districts of North Kona (+184.5 percent) and Puna (+128 percent). In the period between 1980 and 1984, according to state population estimates, Puna had the highest growth rate (+184.5 percent) of all districts on the island. Puna's estimated 1984 population of 16,530 made it the third most populous of the island's nine districts, surpassed only by North Kona (18,226) and South Hilo (44,301) (State of Hawaii, Department of Planning and Economic Development, 1982c).

Puna District Population. Puna's rapid population growth during the 1970s may have stemmed in large part from the abundant supply of relatively low-priced land for residential and/or agricultural purposes. With an area of 495 sq mi, Puna approaches Oahu in size. Great portions of the district were subdivided during the land boom of the 1950s and 1960s. While many of these "ghost subdivisions" were and still are unimproved, scattered new houses have begun to appear throughout the district. Virtually all of Puna's population growth from 1970 to 1980 was outside the three urbanized settlements of Kea'au, Mountain View, and Pahoa, so that the proportion of Puna's population living in these three CDPs fell from 44.5 percent in 1970 to 19.1 percent in 1980.

Table 11-1

CENSUS DATA ON POPULATION AND DEMOGRAPHICS
PERCENTAGE COMPOSITIONS FOR VARIOUS LEVELS OF ANALYSIS

	Hawaii County		Puna District (a)		Keeau (CDP)		Mountain View (CDP)		Pahoa (CDP)	
	1970	1980	1970	1980	1970	1980	1970	1980	1970	1980
TOTAL POPULATION	63,468	92,053	5,153	11,751	951	775	419	540	924	923
	X	X	X	X	X	X	X	X	X	X
ETHNICITY										
Caucasian (White)	28.83	34.02	24.01	43.21	15.25	20.65	16.47	21.48	6.28	8.13
Hawaiian	12.30	18.77	8.77	14.99	N/A	7.74	N/A	8.15	N/A	20.15
Filipino	16.47	13.81	22.36	16.73	N/A	33.68	N/A	13.52	N/A	25.46
Japanese	37.53	26.59	40.71	19.20	N/A	35.35	N/A	50.93	N/A	43.01
Chinese	2.90	1.82	1.65	1.41	N/A	1.03	N/A	2.59	N/A	0.87
other	1.97	5.00	2.50	4.45	N/A	1.55	N/A	3.33	N/A	2.38
AGE										
under 5 years	8.58	9.09	7.78	10.19	8.31	6.19	4.30	6.85	7.36	9.10
5 to 17 years	27.82	21.50	24.22	21.42	22.61	22.06	23.15	17.78	25.32	17.01
18 to 64 years	54.40	59.22	54.94	58.74	57.62	56.26	57.28	58.33	53.03	58.83
65 and older	9.20	10.19	13.06	9.65	11.46	15.48	15.27	17.04	14.29	15.06
PLACE OF BIRTH(b)										
Hawaii	76.99	70.54	72.88	58.85	N/A	63.13	N/A	71.26	N/A	57.00
other U.S.A.	NC	29.07	NC	27.97	N/A	4.36	N/A	7.09	N/A	21.11
foreign country	10.83	9.41	13.61	13.18	N/A	32.51	N/A	21.65	N/A	21.89
RESIDENCE 5 YR. AGO(b)										
same house	62.49	52.89	65.44	44.13	N/A	64.62	N/A	88.29	N/A	48.83
elsewhere on island	NC	22.65	NC	20.12	N/A	24.84	N/A	5.18	N/A	44.14
different island	NC	7.38	NC	9.36	N/A	3.01	N/A	0.00	N/A	3.26
different state	NC	10.07	NC	14.76	N/A	1.76	N/A	0.00	N/A	0.00
different country	NC	2.81	NC	5.58	N/A	5.77	N/A	6.53	N/A	3.78
EDUCATION (pop. 25+)(b)										
8 years or less	37.16	20.11	43.70	18.81	N/A	38.64	N/A	36.87	N/A	43.24
high school grad	31.60	35.52	28.74	36.01	N/A	26.37	N/A	35.28	N/A	22.16
college grad., more	7.54	15.16	5.54	12.75	N/A	12.82	N/A	1.86	N/A	12.79

(a) "Puna District" is comprised of census tracts 210 and 211.

(b) Figures based on 15 percent sample; hence, numbers represent estimate. Percentages may be based on special populations.

"CDP" = "Census Designated Place" "N/A" = "Not Available" "NC" = 1970 categories or bases "Not Comparable" to 1980

Source: U.S. Bureau of the Census, 1970, 1980; State of Hawaii, Community Profiles for Hawaii, 1973; percentages computed by Community Resources

Table 11-2

PUNA POPULATION AS A PERCENTAGE OF THE TOTAL ISLAND,
AND PUNA TOWN POPULATIONS AS PERCENTAGES OF TOTAL PUNA

	Puna District (a) as % of TOTAL ISLAND		Keaau (CDP) as % of ALL PUNA		Mountain View (CDP) as % of ALL PUNA		Pahoa (CDP) as % of ALL PUNA	
	1970	1980	1970	1980	1970	1980	1970	1980
TOTAL POPULATION	8.12%	12.77%	18.46%	6.60%	8.13%	4.60%	17.93%	7.85%
ETHNICITY								
Caucasian (White)	6.76%	16.22%	11.72%	3.15%	5.58%	2.28%	4.69%	1.48%
Hawaiian	5.79%	10.20%	N/A	3.41%	N/A	2.50%	N/A	10.56%
Filipino	11.02%	15.47%	N/A	13.28%	N/A	3.71%	N/A	11.95%
Japanese	8.81%	9.22%	N/A	12.15%	N/A	2.19%	N/A	17.60%
Chinese	4.62%	9.93%	N/A	4.82%	N/A	8.43%	N/A	4.82%
other	10.33%	11.35%	N/A	2.29%	N/A	3.44%	N/A	4.21%
AGE								
under 5 years	7.36%	14.30%	19.70%	4.01%	4.49%	3.09%	16.96%	7.02%
5 to 17 years	7.07%	12.72%	17.23%	6.79%	7.77%	3.81%	18.75%	6.24%
18 to 64 years	8.20%	12.66%	19.36%	6.32%	8.48%	4.56%	17.31%	7.87%
65 and older	11.53%	12.09%	16.20%	10.58%	9.51%	8.11%	19.61%	12.26%
PLACE OF BIRTH(b)								
Hawaii	7.60%	10.65%	N/A	7.75%	N/A	5.23%	N/A	7.42%
other U.S.A.	NC	17.82%	N/A	1.13%	N/A	1.10%	N/A	5.78%
foreign country	10.08%	17.88%	N/A	17.82%	N/A	7.10%	N/A	12.72%
RESIDENCE 5 YR. AGO(b)								
same house	8.47%	10.43%	N/A	11.14%	N/A	9.95%	N/A	8.11%
elsewhere on island	NC	11.34%	N/A	8.38%	N/A	1.14%	N/A	14.34%
different island	NC	16.18%	N/A	2.18%	N/A	0.00%	N/A	2.27%
different state	NC	18.71%	N/A	0.81%	N/A	0.00%	N/A	0.00%
different country	NC	25.35%	N/A	7.01%	N/A	5.18%	N/A	4.42%
EDUCATION (pop. 25+)(b)								
8 years or less	10.39%	11.99%	N/A	16.29%	N/A	10.73%	N/A	18.53%
high school grad	8.03%	12.99%	N/A	5.81%	N/A	5.37%	N/A	4.96%
college grad., more	6.50%	10.78%	N/A	7.97%	N/A	7.80%	N/A	8.09%

* different total reflecting sampling and/or special subpopulations

(a) "Puna District" is comprised of census tracts 210 and 211.

(b) Figures based on 15 percent sample; hence, numbers represent estimate.

"CDP" = "Census Designated Place" "N/A" = "Not Available" "NC" = 1970 categories or bases "Not Comparable" to 1980

Source: U.S. Bureau of the Census, 1970, 1980; State of Hawaii, Community Profiles for Hawaii, 1973; percentages computed by Community Resources

Demographic shifts in Puna from 1970 to 1980 were similar to, but more pronounced than, those experienced by the island as a whole. Ethnically, Puna changed from a largely Japanese to a largely Caucasian area. Also, more than half of Puna's net population growth from 1970 to 1980 was not Hawaii-born. The proportion of Puna's population consisting of native Hawaiians increased from 9 percent in 1970 to 15 percent in 1980 (see Table 11-1). Ten percent of the island's Hawaiian population now resides in Puna (Table 11-3). However, the net additional Hawaiian population was a much smaller proportion of the new Puna population (20 percent) than was the case for Hawaiians island-wide (33 percent), suggesting that the Hawaiian population is unlikely to catch up to the Caucasian population in the foreseeable future (see Table 11-3). In 1980, native Hawaiians were still only the fourth most populous ethnic group (1,762), following Caucasians (5,078), Japanese (2,256), and Filipinos (1,966).

Despite a frequently expressed belief that Puna subdivisions are being filled by retirees, the district's population actually grew somewhat younger during the 1970s. In 1970, people age 65 and older represented 13.1 percent of Puna's population; in 1980 this age group represented only 9.7 percent. The average educational level in Puna rose during the 1970s, but in 1980 the percentage of persons with college degrees was still slightly lower in Puna than for the island as a whole.

The town of Pahoa, which is the nearest CDP to the project site, contained 923 people in 1980, a figure almost identical to its 1970 population. Compared with the Puna District as a whole, Pahoa CDP residents were much more likely to:

- o Be of Japanese ancestry (43.0 percent versus 19.2 percent)
- o Be 65 or older (15.1 percent versus 9.7 percent)
- o Be foreign-born (21.9 percent versus 13.2 percent)
- o Have an eighth-grade education or less (43.2 percent versus 18.8 percent)
- o Have moved recently from elsewhere on the island (44.1 percent versus 20.1 percent)
- o Not to have lived off-island 5 years previously (7.0 percent versus 29.7 percent)

Table 11-3

NET GROWTH COMPONENTS ANALYSIS FOR SELECTED CENSUS CATEGORIES

<u>Changes</u>	<u>Hawaii County</u>	<u>Puna District</u>		
Total 1970-80				
Overall population	28,585		6,598(a)	
Population 25 or older	19,203		3,837	
Employed civilian labor force	12,970		2,026	
Number of families	8,133		1,738	
Year-round occupied housing units	11,977		2,309	
	Change		Change	
	(Raw	Total	(Raw	Total
<u>Selected Categories</u>	<u>Number)</u>	<u>Change (%)</u>	<u>Number)</u>	<u>Change (%)</u>
Ethnicity (overall population)				
Caucasian (white)	13,018	45.5	3,841	58.2
Hawaiian	9,465	33.1	1,310	19.9
Filipino	2,255	7.9	814	12.3
Place of birth (overall population)				
Hawaii	16,072	56.2	3,203(1)	48.1
Education (population 25 or older)				
College graduate or more	5,541	28.9	709	18.5
Occupation (employee civilian labor force)				
Service	2,181	16.8	339	16.7
Industry (employee civilian labor force)				
Construction	809	6.2	313	15.4
Retail	2,951	22.8	258	12.7
Poverty (number of families)				
Families below poverty level	915	11.3	306	17.6
Tenure (year-round occupied housing units)				
Renter-occupied	4,061	33.9	617	26.7
Housing conditions (year-round occupied units)				
1.51 or more persons/room	326	2.7	188	8.1

(a) Because place of birth was based on sample rather than full enumeration, the 1970-80 total change for Puna is calculated as 6,658 rather than 6,598.

Source: U.S. Bureau of the Census, 1970, 1980; State of Hawaii, Dept. of Planning and Community Development, 1973; percentages computed by Community Resources.

No separate or disaggregated census data are available for the subdivisions immediately surrounding the project site, e.g., Leilani Estates or Nanawale Estates. However, indirect evidence from hearings or other public events suggests that residents demographically resemble the Puna-wide population (i.e., tend to be Caucasians new to the Puna area within the past 10 to 15 years). The total population in any of these subdivisions is not currently known. The only currently available information (from tax maps) gives the number of lots in each subdivision as follows:

<u>Subdivision</u>	<u>Number of Lots</u>	<u>Approximate Distance to PGV Project</u>
Leilani Estates	2,266	2,000 feet from northwest boundary (east boundary is 4,000 feet from nearest existing well)
Lanipuna Gardens	110	4,000 feet distant
Nanawale Estates	4,289	1.5 miles distant
Hawaiian Holiday Estates (Nanawale Farm Ranch Lands)	88	1.5 miles distant

Based on a State of Hawaii Department of Health Research Division survey on possible health impacts of geothermal development, some population estimates may be made for Leilani Estates, which is perhaps the most populous area in the immediate vicinity of the project. According to Bruce Anderson, environmental epidemiologist in the Department of Health's Communicable Disease Division, 152 apparent residential structures were counted by state employees (personal telephone communication, April 1984). The survey was based on interviews with persons in 135 of these households (the remainder refused or were not at home). A total of 350 persons lived in these 135 households, for an average 2.59 persons per household. Based on this survey and projections to the full 152 households, the estimated Leilani Estates population in early 1984 was 394.

District Population Trends. Both throughout the island and in the Puna District, population increased substantially between 1970 and 1980. The new population resulted in large part from in-migration. The ethnic composition

of the population became relatively less Oriental, and relatively more Caucasian and native Hawaiian. These trends are likely to continue.

Puna will continue to have great scenic appeal to people seeking an isolated, natural environment and having lifestyles or circumstances that permit a choice of areas in which to live (e.g., retirees or participants in either a subsistence or underground economy). Their demand for Puna land may be more affected by broad national and statewide economic considerations than by the local economy.

Historically, a substantial part of the residential demand for Puna homesites has come from more ethnically diverse people who must find nearby work to support themselves. This demand will be greatly affected by local economic conditions. A level or declining economy in eastern Hawaii will result in level or declining residential property costs in the employment center of Hilo, somewhat reducing the purely economic appeal of living in Puna. It will also reduce the overall new demand for residential development anywhere in eastern Hawaii. But, as is discussed in other sections of this report, there is reason to believe that the economy of eastern Hawaii will improve in the future.

Labor Force

Between 1970 and 1980, Hawaii Island's labor force grew from 25,889 to 41,006, an increase of 58.4 percent, or approximately 4.7 percent per year, compounded. Over the same period, the labor force participation rate held steady at about 60 percent. The growth rate slowed somewhat during the 1980s to an average of 2.8 percent per year, so that by the end of 1984 the labor force stood at an estimated 46,850 (State of Hawaii Department of Planning and Economic Development, 1985).

Economic problems affecting both agriculture and tourism have prevented the number of jobs from increasing as rapidly as the population. Consequently, the county-wide unemployment rate increased from 2.7 percent in

1970 to 9.8 percent in 1982. In 1985 the average Big Island unemployment rate stood at approximately 8.5 percent (State of Hawaii Department of Labor and Industrial Relations, unpublished data, 1986).

For the past several decades, the island has gradually shifted from an agricultural to a tourism-based economy. The 1980 work force was primarily concentrated in nonmanual occupations such as technical/ sales/administrative (26.1 percent), managerial/professional (20.1 percent), and service jobs (16.5 percent). Industries employing island workers showed some evidence of shifting during the 1970s, with proportionately more workers in 1980 employed in retail, financial/insurance/real estate, and public administration (Table 11-4).

In both 1970 and 1980, the Puna District's labor force participation rate was lower than that of the island as a whole, and its unemployment rate was higher. The 1980 census-defined unemployment rate of 12.3 percent for Puna was nearly twice the island-wide figure of 7.0 percent. The state of Hawaii's estimated average 1985 unemployment rate was 14.9 percent for upper Puna and 14.2 percent for lower Puna, contrasted with the island-wide rate of 8.5 percent (State of Hawaii Department of Labor and Industrial Relations, unpublished data, 1986).

Compared with island-wide totals, proportionately more 1980 Puna workers were engaged in manual occupations, such as farming/fishing/forestry and precision/craft/repair workers, or as operators/fabricators/laborers. Similarly, the Puna labor force was more likely to be involved in industries requiring manual skills, such as construction, agriculture, forestry, and fishing. This was particularly true for working residents of Pahoa and Mountain View, where 35 to 40 percent of the labor force is involved in farming-related work. As of 1980, one out of four of Puna's farm industry workers lived in the Pahoa CDP (Tables 11-4 and 11-5).

Table 11-4

CENSUS DATA ON LABOR FORCE CHARACTERISTICS
PERCENTAGE COMPOSITIONS FOR VARIOUS LEVELS OF ANALYSIS

	Hawaii County		Puna District ^(a)		Keeau (CDP)		Mountain View (CDP)		Pahoa (CDP)	
	1970	1980	1970	1980	1970	1980	1970	1980	1970	1980
POTENTIAL LABOR FORCE (aged 16 or above)	43,075	67,205	3,681	8,367	N/A	646	N/A	428	N/A	701
not in labor force	39.46%	38.67%	42.87%	44.68%	N/A	41.33%	N/A	47.90%	N/A	41.23%
armed forces	0.43%	0.31%	0.00%	0.31%	N/A	0.00%	N/A	0.00%	N/A	0.00%
civilian labor force	60.10%	61.02%	57.13%	55.01%	N/A	58.67%	N/A	52.10%	N/A	58.77%
CIVILIAN LABOR FORCE	25,889	41,006	2,103	4,603	N/A	379	N/A	223	N/A	412
unemployed	2.74%	6.96%	4.28%	12.25%	N/A	5.80%	N/A	4.04%	N/A	3.64%
TOTAL EMPLOYED CIVILIAN LABOR FORCE	25,180	38,150	2,013	4,039	N/A	357	N/A	214	N/A	397
OCCUPATION										
service	16.29%	16.47%	9.29%	13.02%	N/A	19.89%	N/A	4.21%	N/A	8.31%
managerial/profess.	NC	20.05%	NC	15.42%	N/A	11.48%	N/A	14.95%	N/A	7.81%
technical, sales & administrative	NC	26.10%	NC	21.64%	N/A	17.09%	N/A	13.55%	N/A	19.65%
farm, fish, forestry	NC	10.29%	NC	15.82%	N/A	10.64%	N/A	33.64%	N/A	36.27%
precision, craft, repair	NC	12.69%	NC	15.15%	N/A	9.24%	N/A	16.82%	N/A	10.33%
operators, fabrica- tors, laborers	NC	14.39%	NC	18.94%	N/A	31.65%	N/A	16.82%	N/A	17.63%
INDUSTRY (selected)										
agriculture, forest, fish, mining	NC	11.20%	NC	16.32%	N/A	10.36%	N/A	46.26%	N/A	40.30%
construction	10.60%	9.11%	7.35%	11.41%	N/A	3.36%	N/A	0.00%	N/A	0.00%
nondurable mfg.	13.34%	6.66%	19.08%	8.27%	N/A	37.82%	N/A	4.21%	N/A	3.27%
retail trade	14.82%	17.52%	13.51%	13.12%	N/A	10.64%	N/A	9.81%	N/A	4.79%
financial, insurance, real estate	2.80%	5.70%	2.43%	4.95%	N/A	2.24%	N/A	0.00%	N/A	4.03%
education	7.61%	8.10%	6.51%	7.95%	N/A	9.80%	N/A	7.48%	N/A	5.29%
public adminis.	6.49%	7.26%	5.71%	8.27%	N/A	2.80%	N/A	11.21%	N/A	5.04%

(a) "Puna District" is comprised of census tracts 210 and 211.

NOTE: All figures based on 15 percent sample; hence, numbers represent estimate.

"CDP" = "Census Designated Place" "N/A" = "Not Available" "NC" = 1970 categories or bases "Not Comparable" to 1980

Source: U.S. Bureau of the Census, 1970, 1980; State of Hawaii, Community Profiles for Hawaii, 1973; percentages computed by Community Resources

Table 11-5

PUNA LABOR FORCE AS A PERCENTAGE OF TOTAL ISLAND:
PUNA TOWN LABOR FORCES AS PERCENTAGES OF TOTAL PUNA

	Puna District ^(a) as % of TOTAL ISLAND		Keauu (CDP) as % of ALL PUNA		Mountain View (CDP) as % of ALL PUNA		Pahoa (CDP) as % of ALL PUNA	
	1970	1980	1970	1980	1970	1980	1970	1980
POTENTIAL LABOR FORCE (aged 16 or above)	8.55%	12.45%	N/A	7.72%	N/A	5.12%	N/A	8.38%
armed forces	0.00%	12.50%	N/A	0.00%	N/A	0.00%	N/A	0.00%
civilian labor force	8.12%	11.23%	N/A	8.23%	N/A	4.84%	N/A	8.95%
CIVILIAN LABOR FORCE	8.12%	11.23%	N/A	8.23%	N/A	4.84%	N/A	8.95%
unemployed	12.69%	19.75%	N/A	3.90%	N/A	1.60%	N/A	2.66%
TOTAL EMPLOYED CIVILIAN LABOR FORCE	7.99%	10.59%	N/A	8.84%	N/A	5.30%	N/A	9.83%
OCCUPATION								
service	4.56%	8.37%	N/A	13.50%	N/A	1.71%	N/A	6.27%
managerial/profess.	NC	8.15%	N/A	6.58%	N/A	5.14%	N/A	4.98%
technical, sales & administrative	NC	8.78%	N/A	6.98%	N/A	3.32%	N/A	8.92%
farm, fish, forestry	NC	16.27%	N/A	5.95%	N/A	11.27%	N/A	22.54%
precision, craft, repair	NC	12.64%	N/A	5.39%	N/A	5.88%	N/A	6.70%
operators, fabrica- tors, laborers	NC	13.94%	N/A	14.77%	N/A	4.71%	N/A	9.15%
INDUSTRY (selected)								
agriculture, forest, fish, mining	NC	15.43%	N/A	5.61%	N/A	15.02%	N/A	24.28%
construction	5.55%	13.26%	N/A	2.60%	N/A	0.00%	N/A	0.00%
nondurable mfg.	11.43%	13.15%	N/A	40.42%	N/A	2.69%	N/A	3.89%
retail trade	7.29%	7.93%	N/A	7.17%	N/A	3.96%	N/A	3.58%
financial, insurance, real estate	6.96%	9.20%	N/A	4.00%	N/A	0.00%	N/A	8.00%
education	6.84%	10.39%	N/A	10.90%	N/A	4.98%	N/A	6.54%
public adminis.	7.04%	12.05%	N/A	2.99%	N/A	7.19%	N/A	5.99%

(a) "Puna District" is comprised of census tracts 210 and 211.

NOTE: All figures based on 15 percent sample; hence, numbers represent estimate.

"CDP" = "Census Designated Place" "N/A" = "Not Available" "NC" = 1970 categories or
bases "Not Comparable" to 1980

Source: U.S. Bureau of the Census, 1970, 1980; State of Hawaii, Community Profiles for Hawaii, 1973; percentages computed by Community Resources

Household Heads

The 1982 Puna Community Survey sponsored by the county and the state of Hawaii provides additional information about work patterns of heads of households (SMS Research, 1982a, pp. 29-31). Using categories based mostly on the official U.S. Standard Industrial Classifications, the survey found the main work activities of Puna household heads to be as follows:

Categories Selected for Highest Percentages or Relevance to Project (778 Households Sampled), %

Retired	23
Unemployed/does not work	8
Construction	12
Sugar	7
Other agriculture	13
Government	8
Drilling/geothermal	1

The survey also inquired about place of work for the household's chief wage earner, with the following results:

Job Location, %

Home/does not work	30
Puna	32
Hilo area	27
Kea'au area	1
Other Hawaii Island area	7
Other reply	2
Does not know/refused	1

Labor Force Trends without the Project

The pattern of Puna population growth suggests that Puna residents will continue to have a lower-than-average participation rate in the labor force and a higher-than-average unemployment rate for those who do participate. Occupations and industries of historical interest to Puna residents have tended to be of an outdoors nature, and this interest can be expected to continue if appropriate opportunities are found.

The Puna Sugar Company completed its phased shutdown in December 1984. The shutdown began on April 1, 1982, with the release of 121 workers. As of late May 1982, only 2 percent had found new employment. Between December 1982 and December 1984, the remainder of the employees were released. Sixty-four employees were retired (State of Hawaii, Department of Labor and Industrial Relations, 1983, pp. 4, 7 and 10; personal communication with Mr. J. Melrose, Agricultural Property Manager, AMFAC, 1986).

Income and Poverty/Affluence Indicators

The island of Hawaii's median 1980 family income of \$19,132 was significantly less than the statewide median of \$22,750. The percentage of families below the official poverty level increased slightly from 9.7 percent in 1970 to 10.3 percent in 1980 (Table 11-6).

In line with its comparatively higher unemployment rate, the Puna District appears to have even greater income and poverty problems than the island as a whole. Median family incomes were lower than county-wide medians in both 1970 and 1980 (Table 11-7). In upper Puna (CT 210), median family incomes trailed island-wide medians only slightly, but the median for lower Puna (CT 211, site of the PGV project) was only 78 percent of the island-wide median in 1970 and just 72 percent of the island-wide median in 1980.

Other indications of increasing poverty in Puna are the percentages of residents in the lower income categories (greater percentages in Puna than on the island as a whole) and the percentage of families below the official poverty level. In 1970, the proportion of families falling in the poverty category was almost the same for Puna (9.9 percent) as for the island as a whole (9.7 percent). In 1980, however, 14.4 percent of Puna's families qualified for poverty status, compared with 10.3 percent island-wide. Although only 13 percent of all the island's families lived in Puna in 1980, 18 percent of the poverty-level families were located there.

In 1980 the Pahoa CDP had a particularly high percentage of families below the poverty level and a lower median family income than the other two Puna CDPs. However, Pahoa also had a higher proportion of families in the upper

CENSUS DATA ON FAMILY INCOME
PERCENTAGE COMPOSITIONS FOR VARIOUS LEVELS OF ANALYSIS

(a) "Puna District" is comprised of census tracts 210 and 211.

"CDP" = "Census Designated Place" "N/A" = "Not Available" "NC" = 1970 categories or bases "Not Comparable" to 1980

11-15

Table 11-7

PUNA FAMILY INCOMES AS A PERCENTAGE OF THE TOTAL ISLAND,
AND PUNA TOWN INCOMES AS PERCENTAGES OF TOTAL PUNA

	Puna District ^(a) as % of TOTAL ISLAND		Keaau (CDP) as % of ALL PUNA		Mountain View (CDP) as % of ALL PUNA		Pahoa (CDP) as % of ALL PUNA	
	1970	1980	1970	1980	1970	1980	1970	1980
TOTAL FAMILIES	8.34%	12.99%	N/A	6.01%	N/A	5.60%	N/A	7.39%
FAMILY INCOME (selected categories)								
less than \$10,000	10.32%	16.51%	N/A	2.27%	N/A	3.82%	N/A	7.05%
less than \$20,000	NC.00%	15.07%	N/A	3.82%	N/A	5.14%	N/A	7.08%
more than \$25,000	4.38%	9.71%	N/A	10.67%	N/A	6.13%	N/A	9.33%
more than \$50,000	4.05%	10.21%	N/A	0.00%	N/A	11.51%	N/A	28.06%
BELOW POVERTY LEVEL:	8.46%	18.21%	N/A	1.87%	N/A	4.22%	N/A	7.73%
MEDIAN FAMILY INCOME:	N/A	N/A	N/A	(more than 100%)	N/A	(more than 100%)	N/A	(more than 100% of lower Puna)
(Census Tract 210:)	85.86%	94.16%						
(Census Tract 211:)	77.98%	72.36%						

(a) "Puna District" is comprised of census tracts 210 and 211.

NOTE: All figures based on 15 percent sample; hence, numbers represent estimate.

"CDP" = "Census Designated Place" "N/A" = "Not Available" "NC" = 1970 categories or bases "Not Comparable" to 1980

Source: U.S. Bureau of the Census, 1970, 1980; State of Hawaii, Community Profiles for Hawaii, 1973; percentages computed by Community Resources

income brackets, thus suggesting that Pahoa has a wider distribution of incomes than either the Puna District or the island as a whole.

Based on baseline economic trend projections without the proposed project, the foreseeable economic future for the eastern portions of the island does not hold forth the prospect of any immediate prosperity. Incomes in Puna will probably continue to trail those for the island, and families qualifying for poverty status will probably continue to be proportionately more numerous in Puna than in other populated parts of the island.

Housing Supply

The supply of year-round housing units on the island grew from 18,972 in 1970 to 33,954 in 1980. This 10-year increase of 79.0 percent was much greater than either the 45.0 percent increase in overall population or the 55.4 percent increase in family units. However, census definitions of housing units include condominium units for resort use or simple investment purposes, which is partially responsible for the apparent 13.9 percent increase in supply and vacancy rates in 1980.

Still, the 69.4 percent increase in year-round occupied housing units (from 17,260 to 29,237) also exceeds the growth in both overall population and family units, thereby indicating fewer persons per occupied housing unit. General improvements in island housing over the 1970s are also indicated by the increased percentages of owner-occupied units (56.9 percent in 1970 versus 60.7 percent in 1980) and decreases in the percentages of units lacking some plumbing and/or having crowded conditions (Table 11-8).

The percentage of the island's total housing located in Puna is approximately the same as the percentages of overall population and total family units (i.e., 13 percent). The vacancy rate is about the same as that for the island as a whole, though Puna has fewer condominium units. Thus, it appears that gross housing supply in Puna is similar to that of the rest of the island.

Table 11-8

CENSUS DATA ON HOUSING STOCK
PERCENTAGE COMPOSITIONS FOR VARIOUS LEVELS OF ANALYSIS

	<u>Hawaii County</u>		<u>Puna District^(a)</u>		<u>Kaau (CDP)</u>		<u>Mountain View (CDP)</u>		<u>Pahoa (CDP)</u>	
	<u>1970</u>	<u>1980</u>	<u>1970</u>	<u>1980</u>	<u>1970</u>	<u>1980</u>	<u>1970</u>	<u>1980</u>	<u>1970</u>	<u>1980</u>
TOTAL YEAR-ROUND HOUSING UNITS	18,972	33,954	1,829	4,404	260	261	120	186	303	301
vacant:	9.02%	13.89%	16.79%	13.01%	2.69%	1.92%	5.00%	5.38%	6.27%	5.65%
TOTAL YEAR-ROUND OCCUPIED UNITS	17,260	29,237	1,522	3,831	253	256	114	176	284	284
TENURE										
owner-occupied	56.87%	60.65%	75.56%	74.18%	74.31%	64.06%	82.46%	77.27%	67.96%	64.08%
renter-occupied	43.13%	39.35%	24.44%	25.82%	25.69%	35.94%	17.54%	22.73%	32.04%	35.92%
SELECTED CONDITIONS										
lacking some plumbing	17.06%	8.12%	31.87%	16.26%	18.18%	5.08%	4.39%	2.84%	43.66%	10.21%
1.51 or more persons/room	6.52%	4.97%	5.65%	7.15%	4.35%	3.52%	4.39%	9.09%	7.75%	8.10%
NUMBER OF OWNER-OCCUPIED NON-CONDOMINIUM UNITS FOR WHICH VALUE DATA AVAILABLE	NC	15,703	NC	2,526	NC	162	NC	114	NC	150
MEDIAN VALUE:	\$24,800	\$70,300	N/A	N/A						
	(Census Tract 210:)		\$16,600	\$54,700	\$15,00-	\$54,200	\$10,000-	\$56,600	\$15,000-	\$59,700
	(Census Tract 211:)		\$19,200	\$47,600	\$19,99		\$14,999		\$19,999	
NUMBER OF RENTER-OCCUPIED CASH RENTAL UNITS FOR WHICH RENTAL DATA AVAILABLE	NC	9,667	NC	727	NC	78	NC	22	NC	74
MEDIAN RENT:	\$54	\$223	N/A	N/A	\$0-\$40	\$110	\$40-\$59	\$165	\$0-\$40	\$135
	(Census Tract 210:)		\$53	\$232						
	(Census Tract 211:)		\$0-\$30	\$260						

(a) "Puna District" is comprised of census tracts 210 and 211.

"CDP" = "Census Designated Place" "N/A" = "Not Available" "NC" = 1970 categories or bases "Not Comparable" to 1980

Source: U.S. Bureau of the Census, 1970, 1980; State of Hawaii, Community Profiles for Hawaii, 1973; percentages computed by Community Resources

For the past two census periods, Puna has had more owner- than renter-occupied units (a 3:1 ratio in both 1970 and 1980), with the owner-occupied percentage exceeding the island-wide percentage. Rentals have constituted a slightly higher proportion (about one-third) of the occupied units in the Pahoia CDP.

Some of the dollar-related statistics (Tables 11-8 and 11-9) reflect Puna's income and poverty problems. In 1980, median values of owner-occupied housing units were significantly lower for Puna than for the island as a whole. In lower Puna (CT 211), where the PGV project would be located, the 1980 median was just two-thirds of the island-wide median value. However, for the same area, median rents were 16.6 percent higher than the island-wide median rental figure. In 1970, Puna rentals were cheaper than average rentals elsewhere on the island.

Puna's housing stock has been generated primarily through custom home construction in land subdivisions. While there is much speculation in Puna land by absentee buyers and sellers, there have been few if any "spec" home developments. Future housing development in Puna will probably continue to be a direct function of the number of people who both wish to and are economically able to purchase land and build houses in the district. Population has generated housing development in Puna, rather than vice-versa. This may change with the new availability of large tracts of formerly agricultural land near Hilo, but no proposals for major residential home development in Puna have yet been made. The general prospect is for continued development of single homes on scattered lots.

Tourism

The island of Hawaii visitor industry, which grew robustly during the 1970s, is just emerging from difficult times in the early 1980s. Westbound visitor arrivals to the island grew from 446,000 in 1970 to a high of 860,000 in 1979. However, a general softening of the tourism market and increased competition from other destination areas resulted in 3 years of declining arrivals to the Big Island. As a result, the westbound visitor total in 1982 was only 678,000, a 20 percent drop. Since 1982, however, the number of

Table 11-9

PUNA HOUSING STOCK AS A PERCENTAGE OF THE TOTAL ISLAND,
AND PUNA TOWN HOUSING AS PERCENTAGES OF TOTAL PUNA

	Puna District ^(a) as % of TOTAL ISLAND		Keeau (CDP) as % of ALL PUNA		Mountain View (CDP) as % of ALL PUNA		Pahoa (CDP) as % of ALL PUNA	
	1970	1980	1970	1980	1970	1980	1970	1980
TOTAL YEAR-ROUND HOUSING UNITS	9.64%	12.97%	14.22%	5.93%	6.56%	4.22%	16.57%	6.83%
vacant:	17.93%	12.15%	2.28%	.87%	1.95%	1.75%	6.19%	2.97%
TOTAL YEAR-ROUND OCCUPIED UNITS	8.82%	13.10%	16.62%	6.68%	7.49%	4.59%	18.66%	7.41%
TENURE								
owner-occupied	11.72%	16.03%	16.35%	5.77%	8.17%	4.79%	16.78%	6.40%
renter-occupied	5.00%	8.60%	17.47%	9.30%	5.38%	4.04%	24.46%	10.31%
SELECTED CONDITIONS								
lacking some plumbing	16.47%	26.23%	9.48%	2.09%	1.03%	.80%	25.57%	4.65%
1.51 or more persons/room	7.64%	18.87%	12.79%	3.28%	5.81%	5.84%	25.58%	8.39%
NUMBER OF OWNER-OCCUPIED NON-CONDOMINIUM UNITS FOR WHICH VALUE DATA AVAILABLE	NC	16.09%	NC	6.41%	NC	4.51%	NC	5.94%
MEDIAN VALUE:	N/A	N/A	(?--ca. 100% of CT 210)	99.09% (of CT 210)	(?--ca. 75% of CT 210)	103.47% (of CT 210)	(?--less than all CT 211)	125.42% (of CT 211)
(Census Tract 210:)	66.94%	77.81%						
(Census Tract 211:)	77.42%	67.71%						
NUMBER OF RENTER-OCCUPIED CASH RENTAL UNITS FOR WHICH RENTAL DATA AVAILABLE	NC	7.52%	NC	10.73%	NC	3.03%	NC	10.18%
MEDIAN RENT:	N/A	N/A	(?--ca. 50% of CT 210)	47.41% (of CT 210)	(?--ca. 100% of CT 210)	71.12% (of CT 210)	(?--ca. 130% of CT 211)	51.92% (of CT 211)
(Census Tract 210:)	98.15%	104.04%						
(Census Tract 211:)	(ca. 50%)	116.59%						

(a) "Puna District" is comprised of census tracts 210 and 211.

"CDP" = "Census Designated Place" "N/A" = "Not Available" "NC" = 1970 categories or bases "Not Comparable" to 1980

Source: U.S. Bureau of the Census, 1970, 1980; State of Hawaii, Community Profiles for Hawaii, 1973; percentages computed by Community Resources

persons visiting the Big Island has begun to increase. The number of hotel rooms on the Big Island has been relatively stable over the past 4 years at just over 7,000, or more than twice the number existing in 1970.

The center for this growth is expected to be in the South Kohala/North Kona area in West Hawaii. With several major projects now under way in South Kohala on the Island's west side, the number of rooms will soon increase sharply. The resulting increase in visitor spending should serve as a major boost to the economy (County of Hawaii, Hawaii County General Plan, Preliminary Draft, May 1986).

The major visitor attractions in the Puna District are Hawaii Volcanoes National Park, the eruptions of Kilauea, and the black sand beach at Kalapana in lower Puna. The Volcano House, a 36-room hotel in the National Park, and Kalani Honua, a hostel-type operation with dormitory accommodations, are the only tourist-related facilities in the district. A significant number of tourists, however, pass through lower Puna on sightseeing excursions and/or on their way to Hawaii Volcanoes National Park, which is the single most popular visitor attraction on the island.

Agriculture

Historically, the sugar industry has played a major role in the economy of the state of Hawaii, and Hawaii County has been the state's largest producer. In 1984, Hawaii County had 70,900 acres devoted to sugarcane, or 37.6 percent of the 188,400 acres of sugar land in the state. The number of acres in cane and the number of jobs in the sugar industry have been declining both statewide and in Hawaii County (State of Hawaii, Department of Planning and Economic Development, 1985, pp. 500 and 502).

Agriculture continues to be a major economic activity in the county of Hawaii. Though acreage in traditional crops such as sugar and coffee declined between 1978 and 1984 by 23.4 percent and 13 percent, respectively (Table 11-10), acreage in selected horticultural and orchard crops increased 31 percent over the same 7-year period. Sugar continued to predominate in value of production, with 1984 sales of \$94 million. This is more than three

Table 11-10

ACREAGE AND SALES VALUE FOR SELECTED AGRICULTURAL CROPS
(Hawaii County, 1978 and 1984)

<u>Crop</u>	Acres (10 ³)		Value (\$ Millions)	
	<u>1978</u>	<u>1984</u>	<u>1978</u>	<u>1984</u>
Sugarcane	92.6	70.9	68.6	94-0
Macadamia nuts	10.1	15.5	11.2	25.9
Flowers and nursery products	0.7	0.9	8.6	16.9
Papaya	1.7	2.1	5.7	7.5
Coffee	2.3	2.0	2.1	4.7

Source: Hawaii Agricultural Reporting Service, 1983, pp. 3, 8, 16, 19, 29, and 38, State of Hawaii Department of Planning and Economic Development, 1985, p. 502.

Compiled by Community Resources, 1986

times greater than the second-ranked crop of macadamia nuts, which had 1984 sales of \$25.9 million. It should be noted that the value of sugar sales increased 37 percent over the 7-year period, whereas the value of macadamia nut sales more than doubled during the same period.

The Puna District has long been a major sugar-producing area, with AMFAC's Puna Sugar Company the primary employer. Although it is anticipated that sugar will continue to play an important role in the county of Hawaii's economy (58 percent of total crop sales in 1984), production in the Puna District has virtually disappeared since the unprofitable Puna Sugar Company ended operations in December 1984. Closing the plantation took approximately 15,000 acres out of sugar production and resulted in the cumulative loss of approximately 485 jobs after the phasedown period.

AMFAC operates a power plant at the closed Puna Sugar Company mill in Kea'au. The company has a firm contract to supply varying amounts of electrical energy to the HELCO electrical grid until the end of 1990. The generator at the mill plant was powered by a sugarcane waste product, as part of the mill operations. Now that bagasse is no longer available, AMFAC has arranged with an independent contractor to provide wood chips as an alternative to the use of fossil fuel. This is a small-scale operation employing 14 people in wood chipping and 25 people at the power plant.

With the cessation of sugar operations in Puna and the consequent release of acreage for other purposes, diversified agriculture has become more important in both relative and absolute terms. According to landowners and corporations doing business in the district, papaya, macadamia nuts, bananas, and flower and foliage production have become the primary commercial agricultural activities in the district since sugar production ceased. A large percentage of the district's papaya and macadamia nut acreage is located in lower Puna. This is expected to expand with the planned opening of Hawaiian Holiday's papaya and hay farm on 2,500 acres of Shipman land. The venture will begin with hay production, to be followed by papaya planting. The two crops will be rotated periodically.

A joint venture comprising AMFAC Hawaii, Hershey Foods, and Kakela Enterprises has recently announced plans to test the commercial feasibility of growing cocoa in Hawaii. The venture will have three phases. Phase I will test a 50-acre site on Maui and/or the Big Island and will last 2 years. Phase II will involve a 350-acre commercial test farm on Maui, the Big Island, and/or Kauai. Phase III will involve independent farmers on 30-acre plots, totaling 3,000 to 6,500 acres of AMFAC land statewide. AMFAC has mentioned its Puna lands as a potential site if the initial tests go well. An additional plus for the Puna area might be the availability of geothermal heat to be used in the drying of the beans.

Science

Scientific research and development, such as the telescope development on Mauna Kea and the OTEC program at Keahole, North Kona, are emerging components of Hawaii County's economy. Astronomy research, for example, has generated over \$52 million in capital investments from outside Hawaii, employed numerous short-term construction workers, and created a total of 106 full-time jobs over the past 10 to 15 years (State of Hawaii, Department of Labor and Industrial Relations, 1983, pp. 4, 7 and 10; personal communication with Mr. J. Melrose, Agricultural Property Manager, AMFAC, 1986). Astronomy is Hawaii's major, and most successful, high-technology industry; continued growth of this activity on the island may encourage companies engaged in complementary high-technology activities (e.g., electronics manufacturing) to locate there.

Industry

Most industrial activities in Puna are related to the agricultural industry, such as processing of sugar, macadamia nuts, and papaya, and generation of electrical power from wood chips. AMFAC Tropical Products (formerly Puna Papaya) operates a processing plant at Kea'au that employs 150 people. In addition to papaya, the plant processes guava supplied by local growers. It has sufficient capacity to process all of the papaya and guava produced on the island in the foreseeable future. C. Brewer's Mauna Loa macadamia nut process plant is also located near Kea'au.

Other primary and secondary economic generators in the Puna area include:

- o Retail trade and cottage industries
- o Two small-scale visitor facilities (Volcano House and Kalani Honua)
- o Commercial fishing
- o Real estate sales

Various government agencies are also major employers in the Puna District.

W. H. Shipman, Ltd. is developing a light industrial park in Kea'au. This park is located along Highway 11, north of Kea'au about 6.5 miles from the airport and harbor in Hilo. Industrial zoning has been obtained for the project, and water lines are being laid. In the Shipman project, 450 acres of land are to be developed in annual increments of approximately 50 to 60 acres. The park is intended to be used for light industrial activities, warehouses, and high-technology research facilities. Several local and foreign businesses have expressed interest in locating there. Given current economic conditions, and the fact that there is a substantial supply of vacant industrially zoned land in Hilo, the rate of development is expected to be very low. However, some potential occupants of the industrial park may benefit from the economic activity associated with further geothermal development in Puna on a long-term basis.

A 2,000-acre resort/residential community has been proposed for King's Landing, located in Puna on the oceanfront adjacent to the South Hilo boundary. Preliminary conceptual plans include a low-rise resort hotel, an 18-hole golf course, low-rise condominiums, single-family residential lots, and low-rise multiple dwelling units. The developer estimates that at full development the resident population of the community will approach 15,000. The process of obtaining state and county approvals and permits has not yet begun, and it would be several years after the permit phase before there are occupied residences on the property. Additionally, the county is reviewing this and all other yet-developed resort-designated lands as to the appropriateness of continuing this designation during the current General Plan update.

Commercial Activities

Commercial activities are located in Kea'au, Pahoa, Kurtistown, Mountain View, Glenwood, Volcano, and Kalapana. A neighborhood shopping center has recently been completed in Kea'au; however, most of the commercial uses in the district are still family-operated businesses serving the adjoining communities (County of Hawaii Planning Department, 1979, p. 44). Puna residents do the majority of their shopping in Hilo and at the new regional center in South Hilo because of the wide variety of stores and merchandise.

Values and Attitudes

Community Values. Puna's residents view themselves primarily as rural and, more specifically, as people who have intentionally chosen such a lifestyle. Table 11-11 lists the best features of life in Puna, as volunteered by the residents of Puna.

Several factors qualify the residents' self-image, however, and make it unique. First, Puna is close to Hilo. Not only do a fair number of Puna residents work there, but they also use the city for recreation, shopping, and government business. In that respect, Puna residents can be considered more suburban than rural. A second qualification is the strong influence of Puna's newcomers. There is no known study that has specifically focused on this group in order to understand how they view their lives and lifestyles. A third qualification is the general resurgence of a distinctly native Hawaiian set of values, which may also strongly influence people's opinions and aspirations.

Certain frequently encountered community values may be particularly relevant to any proposed development in Puna. These include:

- o Family. The concept of intact and extended families is of critical value.
- o Slow pace. Puna's rural quality contributes to the slow pace of life.
- o Land. Subdivision activities have allowed for 1- to 5-acre parcels for residents to grow their own food and to produce crops that can be marketed to supplement their income.

Table 11-11

BEST FEATURES OF LIFE IN PUNA

<u>Item</u>	<u>Percentage of Respondents</u> ^(a)
Population/development (generally lack of such features, e.g., country atmosphere, rural area, uncrowded, etc.)	49
Other physical/environmental (climate, beauty, etc.)	40
Social/lifestyle factors	33
Personal associations/commitments	19
Economic attributes (cheap housing, land, prices)	11
Location/convenience factors (close to Hilo, work, ocean)	11

(a) Percentages can total more than 100 percent because of multiple responses. Sample size = 778.

Source: SMS Research, 1982a, p. 22.

- o Living off the land. Because Puna is largely undeveloped, people can enjoy a variety of activities within the district that are consistent with the Puna lifestyle image, i.e., hunting, fishing, and foraging for plants.
- o The last frontier. Many of the district's newer residents view Puna as the frontier boundary of Hawaii. Its undeveloped character, from their point of view, is associated with the frontier values of rugged independence and self-sufficiency. Living in an active volcanic area adds to this feeling of frontier living.

These values help define what Puna residents might mean by the term "rural." Other, sometimes contradictory, lifestyle values are also operating in the community. For example:

- o Jobs. People in Puna are seriously concerned about the district's economic future. A commonly reported problem in the 1982 survey was lack of opportunity.
- o Services. Although the Puna lifestyle image is one of independence and a pioneering spirit, the residents are demanding better infrastructure and services.
- o Education. People in the Puna area place a high value on education. Education is usually associated with upward mobility and economic success.
- o Underground economy. Marijuana is the economic backbone of Puna's underground economy. Based on anecdotal information, it is surmised that marijuana provides a high cash income for those engaged in its production.

These present values can be expected to persist in the future with or without the proposed project.

Attitudes Toward Geothermal and Other Development. The 1982 survey of Puna dealt with attitudes of residents about future development and, more specifically, their opinions about geothermal energy development. This research was conducted prior to the Kahauale'a contested case hearings held before the State Board of Land and Natural Resources and before the lawsuit, Puna Speaks et al. vs. Hodel et al., received island-wide and statewide publicity. Such publicity could have affected public opinion.

In 1982, most area residents clearly preferred a future economic scenario based on agriculture (Table 11-12). The form of agricultural development desired is vague, but is consistent with Puna's past history and contemporary values. A minority favored industrial growth and more intensive tourism development. Puna residents wanted more jobs and better services but were not, according to the survey, willing to gain such benefits through industrialization. Most people feared that industrialization would bring encroachment, pollution, and loss of rural character.

Most Puna residents were aware of existing geothermal wells, but fewer than 20 percent of those surveyed reported personal impacts: those who felt personally affected reported a negative impact. Reports of impacts decreased the farther away the respondents lived from existing wells.

The following year, the County Planning and Housing Departments sponsored a planning survey with an island-wide sample of 1,055 residents, including a Puna sub-sample of 117 persons (Hawaii Opinion, 1983). One question dealt indirectly with geothermal development. The question was: If you had \$10 million to help industries on the Big Island, how would you use the money? That is, which industries would you put the money into and how would you divide it up? Respondents could allocate this hypothetical money among eight industries, plus an "other industries" category.

Island-wide, 41 percent said that they were willing to help geothermal-related industries. This was sixth behind diversified agriculture (75 percent), tourism (73 percent), aquaculture/fishing (65 percent), construction (53 percent), and sugar (49 percent). Within the Puna subsample, geothermal-related industries fell to seventh place, tied with heavy industry at 24 percent each. This may indicate that Puna residents tend to see geothermal activities and heavy industries as similar (Hawaii Opinion, Inc., 1983, pp. 11, 14, and 15).

Table 11-12

EVALUATION OF DIFFERENT GEOTHERMAL-RELATED
DEVELOPMENT SCENARIOS

<u>Opinion</u>	<u>Percentage of Responses to Geothermal-Related Development Scenario</u>		
	<u>Electricity Only - No Industry</u>	<u>Light Industry</u>	<u>Heavy Industry</u>
Good idea	48 (53) ^(a)	66	21
Not good idea	22 (17) ^(a)	8	44
Depends how it is done	12	9	10
No opinion	18	18	25

(a) 5 percent of the sample opposed geothermal electricity generation (no industrialization) because they thought there should be industrial use of geothermal power in Puna. The figures in parentheses include those responses.

Source: SMS Research 1982a, p. 34.

The most recent survey on attitudes toward geothermal development was a telephone poll commissioned by the Hawaii State Department of Planning and Economic Development's Energy Division (SMS Research, 1986). A total of 227 Big Island residents -- including a disproportionate sub-sample of 103 in the Puna District -- were asked about opinions on three geothermal options: (a) small-scale: a 25 MW development from two plants "in the Kapoho area" with use limited to the Big Island; (b) large-scale: 100 MW to meet all Big Island electrical needs from several plants "in the Kapoho area and further up in the Puna forest"; (c) export to Oahu: 500 MW for export to Oahu via undersea cable after year 2000 from development of several sites, "each on several hundred acres," probably in the Kapoho area and the Puna Forest Reserve.

Overall results are shown below:

	<u>Small-Scale</u>		<u>Large-Scale</u>		<u>Export to Oahu</u>	
	<u>Puna</u>	<u>Island</u>	<u>Puna</u>	<u>Island</u>	<u>Puna</u>	<u>Island</u>
	<u>%</u>	<u>Total</u>	<u>%</u>	<u>Total</u>	<u>%</u>	<u>Total</u>
In favor	66	65	43	47	37	40
Opposed	17	12	29	23	36	32
Depends	14	19	23	23	21	21
Don't Know/ Refused	3	4	5	7	6	8
(Base:)	(103)	(227)	(103)	(227)	(103)	(227)

The overall pattern suggests strong support -- both in Puna and islandwide -- for "small-scale" development such as the presently proposed project, with increasing (but still minority) levels of uncertainty and/or opposition for larger projects. Asked to explain reasons for their answers, most people in favor mentioned need for energy alternatives and economic advantages, while opponents and people who said "it depends" were primarily concerned about environmental impacts.

Native Hawaiian Values. The Puna Hui Ohana, an organization of the Puna Hawaiian community, prepared an assessment of geothermal development impact on

aboriginal Hawaiians in the lower Puna District (Puna Hui Ohana, 1982). According to the Ohana assessment, many of these Hawaiians are attempting to discover and define their own Hawaiian identity while still believing that they must cling to their culture secretly in order to participate and be accepted in the Western culture. They perceive that negative changes are taking place all around them and that Caucasian in-migrants are taking over their culture. They feel like strangers in their own land.

Other concerns expressed in the Ohana assessment include the following perceived possibilities:

- o Geothermal development may result in a loss of access to large areas of undeveloped land that the Hawaiians use for traditional cultural activities such as food and maile gathering and hunting.
- o Geothermal development may encourage a large increase in population that could severely strain public services and infrastructure.
- o Geothermal development may increase the potential for social conflict in lower Puna as relatively highly paid newcomers with different values from the current residents compete for the use of physical resources and social status.
- o Property taxes may rise as a result of land development and this may affect land prices, housing, and farm leases.
- o Increased geothermal development may change aboriginal Hawaiian attitudes regarding interpersonal relationships and the relationship to nature and the supernatural.

Hawaiians have, in recent years, mobilized political and legal resources to stop what they perceive as a loss of cultural identity. Some of these activities involve questioning ownership of various lands and resources, including geothermal energy.

Testimony at the contested case hearings on the proposed Campbell/True/Mid Pac geothermal project in 1983 and 1985 supplied information pertinent to the history of the Pele practitioners. According to Abraham Piianaia, Pele was brought to the islands from Polynesia. Writings of the last 50 years or so

indicate that Kilauea is the home of the goddess Pele. However, as a child, Mr. Piianaia was told by his grandparents that Mauna Loa was the actual home of Pele, but that Pele did some volcanic chores at Kilauea. Homage by true devotees of Pele was paid at Mauna Loa. As Kilauea became more accessible by road, with the establishment of Volcano House at the rim and with increased visitor interest in the area, Kilauea assumed designation as Pele's home.

Some older Hawaiians thoroughly believe that the geothermal resources in the form of steam is Pele's "breath." The notion of drilling wells into the earth to recover this resource is equated, at least by a few, to an attempt to penetrate Pele's lungs and steal her breath away.

Although most Hawaiians have the feeling that Pele is not a wanton or destructive goddess, the destruction of the village of Ho'opu loa by a lava flow in 1926 did away with the long-standing belief that no Hawaiian village would ever be consumed by volcanic action since Pele would protect her people.

The issue of whether geothermal development will interfere with the practice of Pele worship has been brought to court under a First Amendment cause of action. This suit is currently pending.

11.2 ENVIRONMENTAL IMPACTS OF THE PROPOSED ACTION

Employment Impacts

Exact employment and associated economic impacts will depend on ultimate site and engineering plans, now being finalized. Figures in this section are based on a 1984 scenario. It is expected that subsequent changes to this scenario would have only slight implications for the job counts and related economic impacts to be presented here. These preliminary estimates indicate that capital costs for the project will be approximately as follows:

	Capital Cost (\$ Millions)
Plant	25.4
Gathering and injection	4.4
H ₂ S abatement	<u>7.1</u>
Total	36.9

Construction of the power plant and related facilities will be phased over approximately 4 years and will require approximately 50 work years of labor. Peak construction employment on the power plant will be approximately 100 people. During the construction period, daily truck traffic on Pohohiki Road will probably increase. Although it is anticipated that most of the construction skills required are available in the Hawaii county and/or state labor market, a few jobs requiring highly specialized skills may be performed by mainland workers on temporary contracts.

Each geothermal well takes approximately 60 days to drill, and one well will be developed at a time. There is one drilling rig on the island, which is expected to remain full time. Drilling crews will consist of approximately 36 people each (12 per shift, 3 shifts per day); the estimated well drilling costs are approximately \$2 million per well.

Approximately 19 employees will be required for operation and maintenance (O&M) of the facility (Bechtel National, Inc., 1983). The annual operating expenditures are estimated at approximately \$2.3 million, \$800,000 of which is for labor.

Table 11-13 lists the general supervision and construction labor skills classifications required for power plant and ancillary facilities construction. Most of these skills are available either in Puna's or the island's labor force. Skilled former Puna Sugar Company employees would represent a particularly valuable resource. Although no public agency has monitored their current employment status, it is possible that some employees may still be available to work on this project.

As can be seen by the occupational profile of Puna and the job characteristics of the workers being laid off by the Puna Sugar Company, most of the necessary skills are probably available in the district's labor force. In addition, the basic core of required skills to construct the geothermal wellfield gathering system is also available, either in the district or in other areas of the county or state. These skills include certified welders, pipefitters, and steamfitters.

Table 11-13

REQUIRED LABOR SKILLS FOR POWER PLANT CONSTRUCTION

Administrators	Ironworkers
Equipment operators	Laborers
Drivers	Masons
Boilermakers	Painters
Carpenters	Pipefitters, plumbers
Millwrights	Roofers
Concrete workers	Sheetmetal workers
Electricians	Mechanics
Fence erectors	Welders
Glaziers	Well drillers

Source: State of Hawaii, Department of Planning and Economic Development,
1982b p. 8-2.

After the construction period, permanent employees will be required to operate and maintain the fluid transmission systems over the estimated 35-year life of the plant. These job classifications include administrative and support staff, such as clerical, materials, technical, maintenance, and operations personnel. Specialized skills will also be required to perform routine geothermal well maintenance. The majority of the required O&M personnel either are already in the Big Island labor pool or will be trained through on-the-job training programs. Therefore, it is unlikely that it will be necessary to import field O&M personnel to the Big Island either from outside the state or from other islands (State of Hawaii, Department of Planning and Economic Development, 1982b, p. 84).

Table 11-14 summarizes the estimated impact on employment of facility construction and operation.

Construction of the geothermal plant and facilities and drilling of the initial six deep production wells plus one dry injection well will require 50 man-years and 43 man-years of labor, respectively. The preliminary schedule assumes that two wells will be installed prior to site work and construction activities and that the total drilling and construction process will be phased over 4 years. Direct construction employment on the project is estimated to be:

- o Year 1. 288 manmonths (drilling three deep production wells + one deep liquid injection well) + 12 manmonths (drilling four shallow wells) + 5 manmonths (construction) = 348 manmonths or 29 average annual full-time jobs
- o Year 2. 288 manmonths (construction) = 24 average full-time jobs
- o Year 3. 144 manmonths (drilling two deep production wells) + 24 manmonths (construction) = 168 manmonths or 14 average full-time jobs
- o Year 4. 72 manmonths (drilling one deep production well) + 240 manmonths (construction) = 312 manmonths or 26 average full-time jobs

Table 11-14

TOTAL ANNUAL EMPLOYMENT IMPACT OF THE
PGV FACILITY: NUMBER OF JOBS^(a)

<u>Item</u>	<u>Impacts</u>			
	<u>Direct</u>	<u>Indirect</u>	<u>Induced</u>	<u>Total</u>
Construction	23	8	13	44
Operation and maintenance	19	7	19	45

(a) The analysis does not include the employment impacts of drilling nine replacement wells over the 35-year life of the power plant.

Sources: Direct construction employment derived from information supplied by the developer (Bechtel National, Inc., 1983).

Direct operation and maintenance employment from the State of Hawaii, Department of Planning and Economic Development 1982b, p. 8-5.

Simple employment multipliers (direct and indirect jobs per additional direct job) of 1.3525 for the construction industry and 1.3721 for the electricity, gas, and sanitary services sector from State of Hawaii, Department of Planning and Economic Development et al., 1975, p. 23.

Total employment multipliers (direct and indirect and induced jobs per additional direct job) of 1.9054 for the construction industry and 2.3863 for the electricity, gas, and sanitary services sector, *ibid.*

Thus, an annual average of 23 full-time construction jobs will be created over the estimated 4-year construction period. Based on the employment multipliers referenced in Table 11-14, the 23 annual full-time equivalent construction jobs will generate 8 indirect jobs and 13 induced jobs for a total employment effect of 44 new jobs per year over the two-phase, 4-year construction period.

Direct employment required to operate and maintain the plant and geothermal wellfield will be approximately 19 people. Based on the employment multipliers referenced in Table 11-14, these 19 permanent operating and maintenance jobs will generate 7 indirect jobs and 19 induced jobs, creating a total of 45 new jobs. The effect of these new jobs will not be fully felt until the plant goes into commercial production.

Although the number of direct, indirect, and induced jobs created by the construction and operation of the geothermal facility is small, the economic benefits to the island will be positive, including the contribution to reducing the high unemployment rate of the county and district.

Income and Economic Output

Economic activity generated by the project will have an effect on the total economic output and personal income of Hawaii County. Two sources of project expenditure will affect the county:

- o Capital expenditures, which are composed primarily of expenditures on goods, services, and wages involved in the construction phases of the proposed project
- o Operating expenditures, which include salaries paid to permanent employees as well as annual expenditures on goods and services for the operation and maintenance of the facility

Since most of the construction material will consist of large units purchased off-island, expenditures in Hawaii can be assumed to approximate 50 percent of the estimated \$36.9 million total capital costs, or \$18.5 million. In addition, \$14 million will be expended to drill the seven new deep wells. Thus, capital expenditures in Hawaii will be approximately

\$32.5 million. As stated previously, TPC estimates that annual operating expenses will be approximately \$2.3 million. Table 11-15 shows the estimated project contributions to the county's economy.

The projected \$32.5 million in capital expenditures during the 4 years of drilling and construction activity will generate a total output of \$63.2 million, or an annual average of \$15.8 million. Total personal income generated by capital expenditures will total \$16.5 million per year, or an annual average of \$5.5 million.

The total annual economic contribution (direct, indirect, and induced) of operational expenditures will result in an addition of \$4.7 million to Hawaii County's output. Total personal income generated by \$2.3 million in annual operating expenditures amounts to \$1.3 million each year for the 35-year life of the project.

Other Economic Impacts

Property tax will be the primary source of county revenues from the project. Other revenue will be received from motor fuel tax, licenses, and permits. In addition, indirect and induced revenues may result from the increased demand for and production of local goods and services to meet the operational requirements of the geothermal facility.

An analysis of the overall fiscal impact of the proposed development is beyond the scope of this assessment. Because of the public goods nature of government operating expenditures, it is extremely difficult to allocate specific costs, such as road maintenance and other county service costs, to a particular project. In addition, it is impossible to separate the county service costs that might be attributable to geothermal-related employees and their families from the costs incurred in servicing all new households on the island. The impact of the project on county costs will probably be minimal, however, since most of the workers are expected to be drawn from the existing resident labor force.

Table 11-15

ESTIMATED CONTRIBUTIONS OF THE PROPOSED GEOTHERMAL
FACILITY TO THE COUNTY OF HAWAII ECONOMY^(a)

<u>Contribution</u>	<u>Capital Expenditures</u> <u>(\$ Millions)</u>		<u>Operational Expenditures</u> <u>(\$ Millions)</u>	
	<u>Average</u> <u>Annual</u> <u>Output</u>	<u>Average</u> <u>Annual</u> <u>Personal</u> <u>Income</u>	<u>Annual</u> <u>County</u> <u>Output</u>	<u>Annual</u> <u>Personal</u> <u>Income</u>
Direct and indirect	12.2	4.3	2.8	0.8
Total direct, indirect, and induced	20.4	5.5	4.7	1.3

(a) Analysis does not include impacts associated with the drilling of nine additional production wells.

Source: Simple output multipliers (direct and indirect) of 1.2004 for the construction industry and 1.2123 for the electricity, gas, and sanitary services sector, total output multipliers (direct and indirect and induced) of 2.0063 for the construction industry and 2.0579 for the electricity, gas, and sanitary services sector (State of Hawaii, Department of Planning and Economic Development et al., 1975, p.20.)

Simple income coefficients (direct and indirect) of 0.4189 for the construction industry and 0.4396 for the electricity, gas, and sanitary services sector; total income coefficients of 0.5429 for the construction industry and 0.5697 for the electricity, gas, and sanitary services sector (ibid., p.24).

Compiled by Community Resources, 1984.

The state will also derive revenues from the proposed development, including the gross excise tax, corporate and personal income taxes, permit fees, and royalties from the geothermal resource. A portion of the state tax collections is expected to be returned to Hawaii County through grants-in-aid or transfer payments.

Although the state's contribution to geothermal projects from 1972 to 1982 totaled \$3.4 million, the funds have generally been directed to the support of the geothermal industry as a whole (State of Hawaii, Department of Planning and Economic Development, 1982d, p.21). The proposed project has benefited from the state's research and development expenditures, but it is impossible to allocate these costs to any one particular development.

The cost of the state's regulatory and enforcement activities, such as those that are the responsibility of the State Department of Health, may increase as a result of the proposed geothermal development. These costs, which are as yet undetermined, can be considered part of the costs to implement the state's energy policy of encouraging the production of energy from indigenous sources.

In regard to other types of industrial development, certain types of manufacturing activities may find it advantageous if they have access to a source of waste heat. However, TPC has no plans to develop such activities. Several factors make it unlikely that others would successfully develop industrial projects in conjunction with the proposed project. The scale of the project is too small to provide sufficient waste heat for economic development of such projects. Also, the commercial feasibility of projects using waste heat from a geothermal power plant in the context of Puna's existing economy has yet to be demonstrated. It further appears unlikely that support activities and other industrial projects would locate so far from other customers.

In view of the foregoing, it is not expected that substantial industrial development will be generated in the vicinity of the proposed 25 MW power plant. Such development is only likely if development of the geothermal

resource is increased to the point where the level of regular maintenance activity on the power plants will support local service and maintenance industries or until spin-off industries utilizing the by-products of geothermal power production (especially waste heat) become viable.

As a part of the revision of the County General Plan, the county is evaluating the possibility of industrial use designation in the area of the proposed project.

In summary, development of the proposed facility will generate a number of economic impacts that will affect the island of Hawaii. The majority of these impacts are economically positive. Table 11-16 summarizes the major quantitative impacts generated.

Statewide and Island-Wide Energy Implications

The state of Hawaii depends on imported petroleum for over 90 percent of its energy. Energy prices are among the highest in the nation and are over six times what they were in the early 1970s. It is estimated that the state spends over \$1.6 billion per year on imported oil, which is equivalent to about 10 percent of the gross state product (State of Hawaii, Department of Planning and Economic Development, 1985, pp. 348 and 429). Although 25 MW of geothermal-generated power will not greatly reduce this dependency, the statewide and island-wide energy implications discussed below can be attributed to geothermal development.

About 44 percent of Hawaii Island's electrical demand is supplied by generators powered by sugarcane bagasse, wood chips, or some other form of biomass (State of Hawaii, Department of Planning and Economic Development, Energy Office, unpublished data, 1986).

Geothermal development would reduce the state's dependence on expensive, imported fuel oil. Should sugarcane bagasse become unavailable, geothermal energy could be used as an economical replacement. A 25 MW geothermal plant will replace a small percentage of the state's imported oil, which will be a step towards implementing the state policy goal of decreasing dependence on

Table 11-16

SUMMARY OF ECONOMIC IMPACTS GENERATED BY THE FACILITY

<u>Item</u>	<u>Impact</u>
Construction expenditures in Hawaii	\$32.5 million
Average number of direct annual construction jobs generated	23
Annual operating expenditures	\$ 2.3 million
Number of direct permanent operating jobs	19
Total full-time equivalent jobs created	100
Annual personal income generated by annual operating expenditures	\$ 1.3 million
Annual economic output generated by annual operating expenditures	\$ 4.7 million

Source: Community Resources, 1986

imported fuel. Based on HELCO's forecasted requirement of 171,000 MWh additional generation for the first year of operation in 1988, 171.7 million barrels of fuel (469 kWh per barrel with an energy content of 6.2 million Btu) will be replaced by geothermal energy (Hawaii Electric Light Company, 1980, Addendum; Lloyd, personal communication, 1984). Assuming that HELCO will eventually accept 219,000 MWh annually from the 25 MW facility (25 MW x 8,760 hours), 466,951 barrels of oil will be replaced.

Other Economic Activities

Spinoff Activities. Spinoff economic activities as a result of the development and operation of the PGV plant will be minimal, though research on the East Rift Zone geothermal reservoir may be stimulated. The existing HGP-A well can provide only limited data on the nature and extent of the geothermal resource it taps. The operation of six additional production wells will provide the multiple sites needed to conduct drawdown experiments and other studies.

The long-run electric price stability of geothermal generation could encourage business to locate in Hawaii County, especially energy intensive businesses. The proposed facility arguably may also stimulate growth of the proposed Shipman Industrial Park. The park would be a possible location for firms that manufacture, distribute, and/or repair parts and supplies needed by the geothermal facility. However, PGV does not consider "spinoff" activities as having an immediate likelihood of success and does not now plan to be involved in any such activities in conjunction with the proposed 25 MW project. In addition, it could attract research and development firms that might be interested in various aspects of geothermal electricity production or in other commercial applications of the resource itself. The county and state are sponsoring practical research into direct uses of geothermal energy. PGV has already contributed a \$30,000 grant to support this local effort.

Potential Activities That Are Currently Nonfeasible. Other potential activities were investigated and determined not to be feasible, at least at the present time. These are described below.

Direct Use of Geothermal Heat for Papaya Processing (Hawaiian Dredging and Construction Company, 1980). Though the process is marginally feasible from the standpoint of cost, AMFAC's existing processing plant at Kea'au has sufficient capacity to process all of the papaya and guava grown on the island for many years to come. No additional facilities are needed.

Use of By-Products from Geothermal Operations, Primarily Those Resulting from Pollution Control (Thomas, 1982). The study examined a facility that would produce approximately 1.650 tonnes (1.818 tons) of elemental sulfur per year. Elemental sulfur can be used as a binder or filler in sulfur-aggregate concrete, and sulfur-extended asphalt shows promise for road paving. The development of a spinoff industry to utilize sulfur by-products will probably be economically feasible only when generation exceeds 200 MW; at that level of geothermal development, fertilizer plants that use the sulfuric acid by-products of geothermal pollution control may also be feasible.

Heavy Industrial Activities, such as Manganese Nodule Processing. This type of activity will probably not occur unless development of the geothermal resource approaches 500 MW. A nominal processing facility would require about 2.4 million MWh per year, or a firm power requirement of about 275 MW (State of Hawaii, Department of Planning and Economic Development, 1981, p. 203). Whether or not the industry is developed in Hawaii will also be influenced by external factors such as the competitive advantages offered by other areas with cheaper land and labor costs.

Diversified Agriculture. Diversified agriculture is expected to continue to expand in Puna with or without development of the project. Agriculture is compatible with geothermal development since it does not require a buffer zone between the facility and fields to minimize negative impacts. In this respect, it is preferable to residential development near the facility. As discussed earlier, the agricultural base of the Puna District is shifting from extensive crops such as sugar to more intensive operations. Though the proposed project site is located on agriculturally zoned land, there is a sufficient supply of land in other areas of Puna to support a viable, growing agriculture industry.

Population, Labor Force, Income, and Housing Supply

Because employment generated by this project is expected to be largely supplied by the existing labor force, and because no secondary industrial activities are anticipated, indirect population impacts should be small. Geothermal drilling personnel are already island residents. It should be necessary to import only a few construction personnel. Assuming that all imported workers will bring their families and that all will be present at the same time, the population growth impact will probably still be modest. The operational-phase employment of 19 persons will have even less effect.

Hawaii Island's and Puna's labor force composition will not be affected, and the types of jobs provided by the project will be compatible with the occupational skills and backgrounds of Puna's current labor force. The mechanical nature of the geothermal construction and maintenance jobs will generally match the skills of employees being discharged from the Puna Sugar Company.

Anticipated income for project workers is likely to be, on average, somewhat higher than current median income for residents of the island in general or of Puna in particular.

The area housing supply will be adequate for the projected work force in both construction and operational phases.

Lifestyle

The PGV project will have little, if any, tangible impact on Puna's wealth or general lifestyle. For some people, however, it may have symbolic importance. The project is Hawaii's first large-scale commercial application of geothermal technologies that have developed over the past decade. As such, it represents a major step toward significant energy production activities in Puna. For some people, this symbolizes progress, opportunity, and economic development. For others, it may mean unwanted industrialization and encroachment on the traditional rural atmosphere and slow pace of life.

11.3 PROPOSED MITIGATION MEASURES

Community Involvement Programs

Puna residents have shown a strong desire to be involved in geothermal planning though there is no clear channel for such involvement at this time, except for seats on statewide advisory panels. Because the government's role in geothermal power is more regulatory than action-oriented, private developers are in a better position to involve community groups in meaningful ways. Ways to encourage community involvement in the project should be studied and implemented as a potential mitigation for resident apprehension about geothermal development. The following organizations have already been active in providing a local forum for discussion of geothermal development:

- o State Geothermal Advisory Council
- o Mayor's Advisory Committee
- o Big Island Business Council
- o Hawaii Island Economic Development Board
- o Hawaii Island Chamber of Commerce
- o Puna Geothermal Venture Advisory Committee

It should be noted that most community residents do not oppose all forms of economic spinoff activities from geothermal development; rather, they oppose heavy industry and support cascading uses of heat for agriculture-related activities (SMS Research, 1982a). Hence, any community involvement program should consider ways that residents can educate themselves about the feasibility of such activities, including the formation of community development corporations.

Contingency Management Plans

Because many community fears about geothermal development are based on misinformation, potential industry spinoffs, and/or ultimate statewide export of geothermal power, state and county government planners can help allay these concerns by developing a blueprint for a planning and management process. This process should specify exact studies and management decisions to be

undertaken if the present initial geothermal development does lead to a second generation of development for Puna. This plan will reassure the community that concerns will be addressed at the proper time rather than being continuously dismissed as "not yet relevant." It should also outline the role community members can play in broader geothermal development planning.

Section 12
Cultural Resources

Section 12

CULTURAL RESOURCES

12.1 ENVIRONMENTAL SETTING

The cultural resources in the site area were studied in a 1-mile-wide (2,010-acre) concentric area centered on the proposed project site in Puna (Rodgers-Jourdane and Nakamura, 1984). This area includes at least eight ahupua'a, or land divisions, within the Puna District: Kani-a-hiku, Hale-ka-mahina, Kapoho, Ahalunui, Lae-pao'o, Oneloa, Pohoiki, and Keahi-a-laka. The cultural resource baseline study concentrates on Kapoho, as it is the largest portion within the project area.

Cultural History

Circa AD 1475, Puna was one of six districts of the island of Hawaii. The chiefs of the six districts acknowledged Liloa as their supreme chief, but with his death the unity of the six districts was temporarily destroyed. 'Umi was a son of Liloa, but not the acknowledged heir to the title of supreme chief. However, by conquest, 'Umi reunited the kingdom (Barrere, 1959, p. 15). The complex and interesting history of Puna, from this period of conquest by 'Umi to the military conquest and control of Hawaii Island by Kamehameha in 1791, is told by Barrere, 1959.

Puna as a Religious Center

Puna was an important center in the development of Hawaiian religion. It was in Puna that Paa first established his line of priesthood, a line that continued until after the death of Kamehameha I in 1819 (Beckwith, 1979, pp. 371-375). The first heiau, or pre-Christian place of religious worship, constructed by Paa was at Puna (Thrum, 1907a, p. 48). Other heiau in the Puna District are noted in Thrum (1907b). One heiau, Kukii, is listed at Kapoho, and another is listed at Pohoiki, a subdistrict of Puna next to Kapoho.

Population Estimates, 1778-1850

The total population of the Hawaiian Islands for the years 1778 to 1779, when the British naval captain James Cook and crew arrived, has been estimated to be 300,000. The population of the island of Hawaii is estimated to have been 100,000 to 150,000. By the time of the first missionary census (1831-1832), the population of the island of Hawaii had declined to 45,792, and in the 1950 census to 25,864 (Schmitt, 1968).

Land Commission Awards in the Mid-Nineteenth Century

Land tenure in Hawaii changed fundamentally in the mid-nineteenth century when fee-simple, private ownership of land was legalized through a complex of laws commonly referred to as the Great Mahele. As a result of this change from a feudal system to private ownership of land, the Puna area was divided and ownership of various portions was awarded to certain individuals.

In Puna, a small number of individuals were awarded unusually large acreages by the Land Commission (Hawaii [Territory], 1929, p. 500). Some of the Land Commission Awards in the 1-mile radius of the study area included:

- o 4,060 acres at Kapoho to C. Kanaina, father of W. C. Lunailo
- o 5,562 acres at Keahialaka, a subdivision of Puna adjacent to Kapoho, to W. C. Lunailo, king of the Hawaiian Islands from 1873 to 1874
- o 2,902 acres in Puna to Hazaleleponi Kalama, adopted daughter of C. Kanaina and Miriam Ke-ka-ulu-ohi and wife of the third king of the Hawaiian Islands, Kau-i-ke-aouli

Historic Trails in the Area

An 1895 Hawaiian Government map and survey by A. B. Loebenstein shows trails in the area of Pu'u Honua'ula, close to the center of the project area. The famous Ellis Trail, traveled by the missionary William Ellis in 1823, passes through nearby Kapoho (Ellis, 1979, pp. 296-323), and may be connected with some of the trails in the project area. Roads in the project area should be considered in relation to this historical process of ancient Hawaiian trails becoming roads.

12.2 IMPACTS ON CULTURAL RESOURCES

Since there are no known cultural resources at the proposed project site, there will be no anticipated impacts on cultural resources from clearing, construction, operation, or plant decommissioning (Rodgers-Jourdane and Nakamura, 1984).

Section 13
Alternatives to the Proposed Action

Section 13

ALTERNATIVES TO THE PROPOSED ACTION

13.1 NO ACTION ALTERNATIVE

The no action alternative is defined as no geothermal development on this leasehold. The no action alternative means a continued reliance on imported oil and petroleum products as the primary energy source on the island of Hawaii. Currently, the state of Hawaii obtains approximately 90 percent of its energy supply from imported petroleum.

The no action alternative eliminates all potential impacts identified in Sections 3 through 12 for the PGV. Unavoidable adverse impacts of the PGV that would be avoided by this alternative include:

- o Controlled quantities (within established regulatory standards) of air emissions during well drilling and testing, construction, and operation
- o Controlled discharges (within regulatory standards) to geothermal groundwater during well drilling and testing and from injection operations
- o Alterations of site topography resulting from excavation and grading
- o A 12-acre commitment of land
- o Loss of natural vegetative communities and wildlife habitat
- o Increased erosion resulting from soil disturbance
- o Disturbance of resident wildlife
- o Alteration of the aesthetic character of the area resulting from removal of vegetation, change of land forms, installation of structures, steam plumes, and noise
- o Controlled noise associated with the various phases of project development and operation
- o Increase in traffic during construction

The no action alternative also eliminates positive economic impacts associated with the PGV, including capital expenditures on goods services, increased employment during construction and operations, and county revenue (e.g., property taxes), and state royalties.

The no action alternative is counter to the goal of increased energy self-sufficiency which forms the basis for state and the county plans. Relying on oil imports for 90 percent of its energy supply, the state has a dependence that is disproportionate compared with that of other states and represents an excess of \$1 billion in payments flowing out of the Hawaiian economy each year. Because the state is rich in alternative renewable energy sources that are becoming available through new or improved technologies, the state and county plans direct the attainment of greater energy self-sufficiency through replacement of imported petroleum with power generated from renewable resources. The PGV geothermal power plant's use of an indigenous energy source would displace approximately 250,000 barrels of oil per year and would be in accord with the state's goal of increased energy self-sufficiency. The no action alternative, continued reliance on imported petroleum, is clearly in conflict with the energy goals of the state.

Also, the no project alternative is not a "no energy" alternative, but one that derives electrical power from other energy sources, probably fossil fuel. Hence, the no project alternative also has environmental impacts, such as air quality deterioration from the combustion of fuels, associated with it. Even though these impacts occur elsewhere, i.e., around other power plants, they are just as real.

13.2 ALTERNATIVES WITHIN THE PROPOSED ACTION

Alternative Hydrogen Sulfide Abatement System

The proposed action will control H_2S emissions by injecting the noncondensable gas stream into a nonreservoir rock stratum. As discussed in Section 2.4, if the injection system will not control H_2S emissions sufficiently to meet the specified standards, the RT-2 system developed by Dow will be used to abate the H_2S . In the RT-2 system, the noncondensable gases

are thermally oxidized and scrubbed with caustic soda (NaOH). The condensate is treated with a regenerative iron compound. The two fluid streams are combined to produce environmentally acceptable sulfate and sulfite compounds that are dissolved in the condensate and injected into or near the reservoir with the blowdown. This system represents the state of the art in surface chemical treatment of H_2S from geothermal resources; a similar system is currently in use at the HGP-A power plant.

Injection is the preferred approach because it minimizes waste stream handling and disposal and reduces problems associated with handling and transporting hazardous chemicals.

13.3 ALTERNATIVES CONSIDERED BUT ELIMINATED FROM FURTHER STUDY

Alternative Power Sources

The state of Hawaii is committed to increasing its energy self-sufficiency by developing its indigenous natural power sources, thereby reducing its reliance on oil as a power source. In addition to the use of geothermal resources, these power sources include:

- o Hydroelectric
- o Ocean thermal conversion
- o Solar
- o Photovoltaics
- o Wind
- o Biomass
- o Municipal solid waste

Hydroelectric power is currently used on a limited and seasonable basis, but the geologic nature of the island does not lend itself to hydroelectric development on a large scale. Hydroelectric power facilities that have been proposed are too small to decrease the demand for imported oil significantly. Experiments with ocean thermal energy conversion have been conducted off the

Hawaiian coast for several years. Although ocean thermal energy is technically feasible, its cost is prohibitive unless the economics improve substantially.

Under certain circumstances, solar, photovoltaic, and wind power may be viable options. All three options have been studied or operated on a limited scale in Hawaii. However, these options are not currently economically competitive with geothermal power. In addition, because of the small-scale and intermittent generation capacity, these options are not suitable as a base-load source of electricity to replace imported oil.

The potential use of biomass as an energy source is currently not a preferable alternative to geothermal development. Although biomass (e.g., trees, bagasse) may be used to produce energy, there is no economically viable, established biomass energy technology other than its use as a fuel source. In 1980, biomass was estimated to supply nearly 2 percent of the United States' annual energy, predominantly in the form of wood wastes used as fuel by the paper and pulp industry (Rose and Miller, 1983). In Hawaii, bagasse is the primary source of biomass fuel and supplies about 25 percent of the islands' energy. Biomass energy production based on intensive silviculture is not currently a viable energy source because of conflicts with land use, the value of wood as other products, and potential long-term adverse environmental impacts (OTA, 1983). Although biomass energy conversion has beneficial aspects (e.g., resource renewability, lower sulfur content than oil or gas), it also has environmental and economic constraints (e.g., soil erosion and hydraulic run-off associated with removing forest or crop residues) that may negate the economic benefits of such energy harvest (Rose and Miller, 1983).

The use of municipal solid waste as a power source or power supplement is technically feasible, but would require considerable volumes of combustible materials consistently and readily available to supply a reliable base-load source. In addition, there are air quality concerns associated with burning waste, and the construction and operation of such a system would cost more than geothermal power.

For these reasons, use of geothermal energy is the most economical and reliable indigenous power source. Other indigenous power sources were not considered as viable alternatives to this project at this time.

Alternative Site

The site selected for the proposed project was based on the knowledge of the existing geothermal reservoir in the Puna District. The criteria used in selecting this site are provided below.

Areas Outside of the Leasehold of Interest. The area considered for potential sites was limited to the designated leasehold area and to areas within 1/2 mile of the three existing PGV geothermal wells because of economic and physical constraints.

Topography. Because areas of steep or erratic topography may result in higher construction costs and design constraints, the two cinder cones at Pu'u Honua'ula were excluded.

Areas Requiring Extensive Earthwork. Areas in the study area requiring extensive earthwork were excluded under the topography criterion.

Compatibility with Soils, Geology, and Seismology. Aa lava was preferred to Pahoehoe lava because of the increased probability of flow tubes, cavities, etc., in the Pahoehoe lava. Areas most susceptible to lava flow were excluded based on the 1981 report by Slemmons, et al.

Soil conditions will not affect foundation stability because the thin soil layers will be scraped away during construction. Available information on fissures and faults does not appear to differentiate between potential sites in the study area.

Visual Impacts. The area of greatest visual sensitivity is along Highway 132 and in the housing development northwest of the study area. Preference was given to potential sites south and southwest of the Pu'u Honua'ula cinder cones.

Compatibility with Productive Lands. Soils in the Keaukaha, Opihikao, and Malama Series all have higher productive capability than aa lava flows, Pahoe-hoe lava flows, or cinder land. Areas with soils of higher productive capability were downgraded.

Potential Noise Impacts. Areas most sensitive to noise impacts were assumed to be the same as those sensitive to visual impacts. Because of the shielding effect of the cones, sites south and southeast of the Pu'u Honua'ula cinder cones will have less noise impact on the more sensitive areas north and northwest of the study area. Areas downgraded because of noise considerations are the same as those downgraded for visual aesthetic considerations.

Potential Air Quality and Ecosystem Impacts. Prevailing daytime winds are from the northeast, and prevailing nighttime winds are from the west and northwest. Preference was given to areas south and southeast of the Pu'u Honua'ula cinder cones to avoid potential plume effects on vegetation and wildlife.

The project site selected was the only portion of the study area that had no identified negative characteristics. The site selected is the one most suitable for making maximum use of the known reserve.

In addition, an existing geothermal facility lies not far to the southwest. The location of the proposed project at the selected site will minimize potential land use conflicts. No areas outside the PGV project area boundaries or the proven geothermal resource were evaluated for the proposed project.

Section 14
Unavoidable Adverse Environmental Impacts

Section 14

UNAVOIDABLE ADVERSE ENVIRONMENTAL IMPACTS

Most of the potential impacts of project development identified in Sections 3 through 12 will be mitigated, and recommendations for mitigations are discussed in each section. However, development of the PGV project will have some adverse environmental impacts that cannot be completely mitigated or avoided.

Most of the unavoidable impacts from project development will occur throughout the 35-year life span of the project. These impacts include:

- o Slight or minimal alterations to topography
- o Controlled quantities of air emissions during well drilling and testing and construction operations (within regulatory limits)
- o Controlled quantities of air emissions during power plant operation (within regulatory limits)
- o Controlled discharges to geothermal groundwater during well drilling and testing (within regulatory limits)
- o Controlled discharges to geothermal groundwater from injection operations (within regulatory limits)
- o Commitment of 12 acres of land for the power plant and associated facilities
- o Visual interruption
- o Controlled noise during construction, well drilling and testing, plant operation, and decommissioning (within regulatory guidelines)
- o Increased traffic during construction

After project decommissioning, many of these impacts will be mitigated through site restoration activities. When plant operations cease, buildings will be removed, wells will be sealed, and the land will be made available

for other uses. The impacts of air emissions and discharges to geothermal groundwater will not be reversed, but they will cease at the time of project decommissioning. As stated in Sections 5 and 6, air and water quality impacts will be minor and will be controlled to adhere to strict state and county environmental regulations.

Section 15
Irreversible and Irretrievable Commitment of Resources

Section 15

IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

The PGV project will involve the commitment of land, geothermal fluids, labor, building materials, and private capital. The irreversible and irretrievable commitments of resources include the labor and building materials necessary to construct and operate the proposed geothermal facilities and the associated capital development costs.

For the 35-year life of the project, approximately 12 acres will be committed for the geothermal facilities. Because of the project's temporary nature and the restoration potential of the land following project shutdown and removal of the facilities, this commitment of land is not considered irreversible or irretrievable. As discussed in Section 3, the land taken from papaya orchards can be returned to agricultural use.

The performance of geothermal reservoirs over time and the possible depletion or cooling of the resource are major uncertainties in geothermal development. Therefore, no one knows at this time whether tapping a geothermal reservoir for steam production is an irreversible or irretrievable commitment of the heat resource. Although temperature fluctuations have been observed in geothermal production wells throughout the world, the variations have been attributed largely to cooler water recharging the reservoir and not to a change in the heating potential of the reservoir.

As mentioned in Section 4, the island of Hawaii is one the most active volcanic areas in the world. The PGV project is sited near the Kilauea Volcano, the most active eruptive center on the island. It is extremely improbable that removing the relatively small amount of heat energy required to meet the power plant requirements will have a significant cooling effect on the geologic process. Also, because of the reservoir's highly permeable rock, the high rainfall in the Puna District, and the island's hydrologic conditions, it is improbable that the reservoir will dry out.

Section 16
Necessary Permits and Approvals

Section 16

NECESSARY PERMITS AND APPROVALS

Table 16-1 identifies the permits and approvals applicable to the PGV project at the present time and the enabling legislation that provides for the regulatory requirement.

Table 16-1

APPLICABLE PERMITS, APPROVALS, AND THE ENABLING LEGISLATION

Permits and Approvals

Enabling Legislation

Federal Permits

Prevention of Significant Deterioration
(PSD) Permit

- o 91 Stat. 685-796 Clean Air Act Amendments of 1977
- o 40 CFR 52.21, PSD Regulations

State Permits

Department of Health (DOH)

- o Authority to Construct or Modify a Facility; Permit to Operate

- o Clean Air Amendments of 1977, Public Law No. 95-95
- o 40 CFR 52.21, PSD Regulations
- o Hawaii Revised Statutes, Chapter 342
- o Administrative Rules of the DOH, Title 11, Chapters 59 and 60

- o Underground Injection Control Permit-Approval to Construct; Approval to Operate

- o 40 CFR 122 and 146, Regulations and Technical Criteria and Standards; State Underground Injection Control Programs
- o Hawaii Revised Statutes, Chapter 340E
- o Administrative Rules of the DOH, Title 11, Chapter 23

Department of Land and Natural Resources (DLNR)

- o Geothermal Exploration Permit

- o Hawaii Revised Statutes, Chapters 177, 178, and 182
- o Administrative Rules of the DLNR, Title 13, Chapter 183, Subchapter 2

- o Geothermal Well Drilling Permit

- o Hawaii Revised Statutes, Chapters 177, 178, and 182
- o Administrative Rules of the DLNR, Title 13, Chapter 183, Subchapter 8

- o Modification of Geothermal Well for Injection Use Permit

- o Hawaii Revised Statutes, Chapters 177, 178, and 182
- o Administrative Rules of the DLNR, Title 13, Chapter 183, Subchapters 8 and 9

Table 16-1 (Cont'd)

Permits and Approvals

Enabling Legislation

State Permits (Cont'd)

o Abandonment of Geothermal Well Permit

o Hawaii Revised Statutes, Chapters 177, 178, and 182
o Administrative Rules of the DLNR, Title 13,
Chapter 183, Subchapters 8 and 11

o Geothermal Mining Lease

o Hawaii Revised Statutes, Chapter 182
o Administrative Rules of the DLNR, Title 13, Chapter 183

o Permit to Drill, Deepen, Redrill, Plug,
or Alter a Water Well and to Install,
Replace, or Modify a Pump

o Hawaii Revised Statutes, Chapters 177 and 178
o Administrative Rules of the DLNR, Title 13,
Chapter 166, Subchapter 8

Department of Land and Natural Resources (DLNR)

o Geothermal Plan of Operations

o Hawaii Revised Statutes, Chapters 177, 178, and 182
o Administrative Rules of the DLNR, Title 13,
Chapter 183, Subchapter 7

Department of Labor and Industrial Relations (DLIR)

o Pressure Vessel/Boiler

o Hawaii Revised Statutes, Chapter 397
o Administrative Rules, Title 12, Subtitle 8,
Chapters 210, 220-224

County Permits

o Geothermal Resource Permit

o Hawaii Revised Statutes, Chapter 205
o Hawaii County Charter, Section 5-4.3, Section 13-7
o Hawaii County Planning Commission, Rule 12

o Building Permit

o Hawaii County Code, 1983, Chapter 5
o Hawaii County Code, 1983, Chapter 14, Article 9

o Electrical Permit

o Hawaii County Code, 1983, Chapter 9, Article 5, Division 1

Table 16-1 (Cont'd)

Permits and Approvals

Enabling Legislation

County Permits (Cont'd)

- o Plumbing Permit
- o Grading Permit
- o Grubbing Permit
- o Stockpiling Permit

- o Hawaii County Code, 1983, Chapter 17, Article 2
- o Hawaii County Code, 1983, Chapter 10, Articles 2 and 3
- o Hawaii County Code, 1983, Chapter 10, Articles 2 and 3
- o Hawaii County Code, 1983, Chapter 10, Articles 2 and 3

Section 17
Literature Cited

Section 17

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Appendix
Noise Monitoring Instrumentation and Procedure

Appendix

NOISE MONITORING INSTRUMENTATION AND PROCEDURE

INSTRUMENTATION

The noise monitor systems consisted of Metrosonics, Model dB-604, programmable sound level analyzers, each equipped with an Electret condenser microphone, microphone preamplifier, microphone windscreen, and an anemometer wind sensor. A portable digital printer was used to retrieve the data from the monitor after each 24-hour measurement period. In addition to these systems, an octave band sound level analyzer was used to sample the ambient noise levels during each test period. Each measuring system was calibrated daily. Instrumentation is listed in Table A-1.

PROCEDURE

Prior to the start of the noise monitoring survey, a functional check was performed on all measuring systems. A field calibration, using a Gen Rad 1986 sound level calibrator set to 94 dB at 1,000 Hz, was performed on each monitor system before and after each monitoring period.

After the monitors were programmed and positioned at the selected monitoring locations, the microphones and preamplifiers were weatherproofed for protection against adverse weather conditions, and a windscreen was placed on each microphone to reduce the effects of wind on the noise measurements. The wind anemometer was set to inhibit data collection when the wind speed exceeded 12 mph. The microphone systems and anemometers were placed between 6 and 7 feet above ground on either a tripod or a post.

Table A-1

INSTRUMENTATION

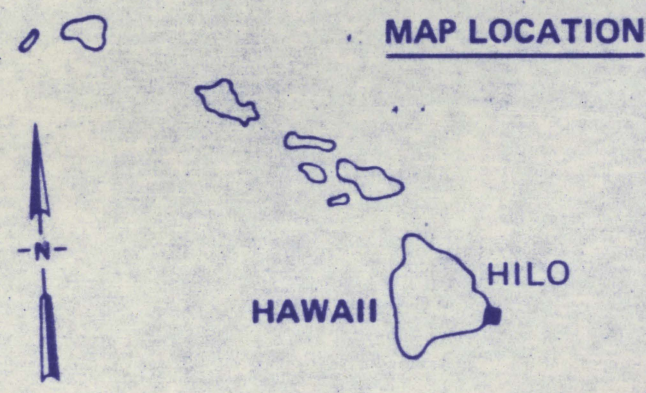
Noise Monitor Systems

<u>Quantity</u>	<u>Description</u>
2	Metrosonics Model dB-604 Sound Level Analyzer S/N 1068 and S/N 1071
2	Gen Rad 1961-9610 1-inch Electret Condenser Microphone S/N 10311 and S/N 10207
2	Gen Rad 1560-P42 Microphone Preamplifier S/N 5886 and S/N 4450
2	Metrosonics WS 603 Anemometer Wind Sensor
2	Gen Rad 1560-7553 Microphone Wind Screen
1	Metrosonics dB-421 Portable Digital Printer
1	Gen Rad 1986 Omnical Sound Level Calibrator S/N 00108

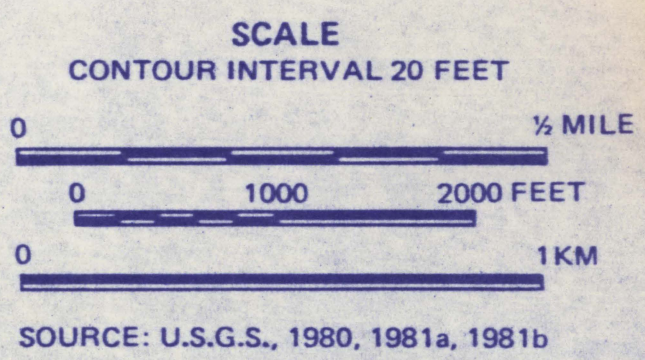
Octave Band Sound Level System

<u>Quantity</u>	<u>Description</u>
1	Brue1 & Kjaer 2215 Precision Sound Level Meter/Octave Analyzer S/N 726052
1	Brue1 & Kjaer 4165 1/2 in. Condenser Microphone S/N 682550
1	Brue1 & Kjaer UA 0237 Microphone Wind Screen





- LEGEND**
- C Cultivated areas
 - C(f) Fallow fields
 - cM Closed *Metrosideros* forest
 - oM Open *Metrosideros* forest
 - oM(S-L) Open *Metrosideros*-Lichen forest
 - oMD Open *Metrosideros*/*Diospyros* forest
 - oM-P Open *Metrosideros*-*Psidium* forest
 - mf Mixed forest
 - s Scrub
 - R Residence
 - *Bobea* sp.
 - ▲ *Cyrtandra* spp.
 - *Tetraplasandra hawaiiensis*
 - Study Area Boundary



**PUNA
GEOTHERMAL VENTURE PROJECT
HONOLULU, HAWAII**

**Figure 7-1
VEGETATION MAP**

BECHTEL GROUP INC.	JOB. NO.	DRAWING NO.	REV.
	15722		